AIRLOCK

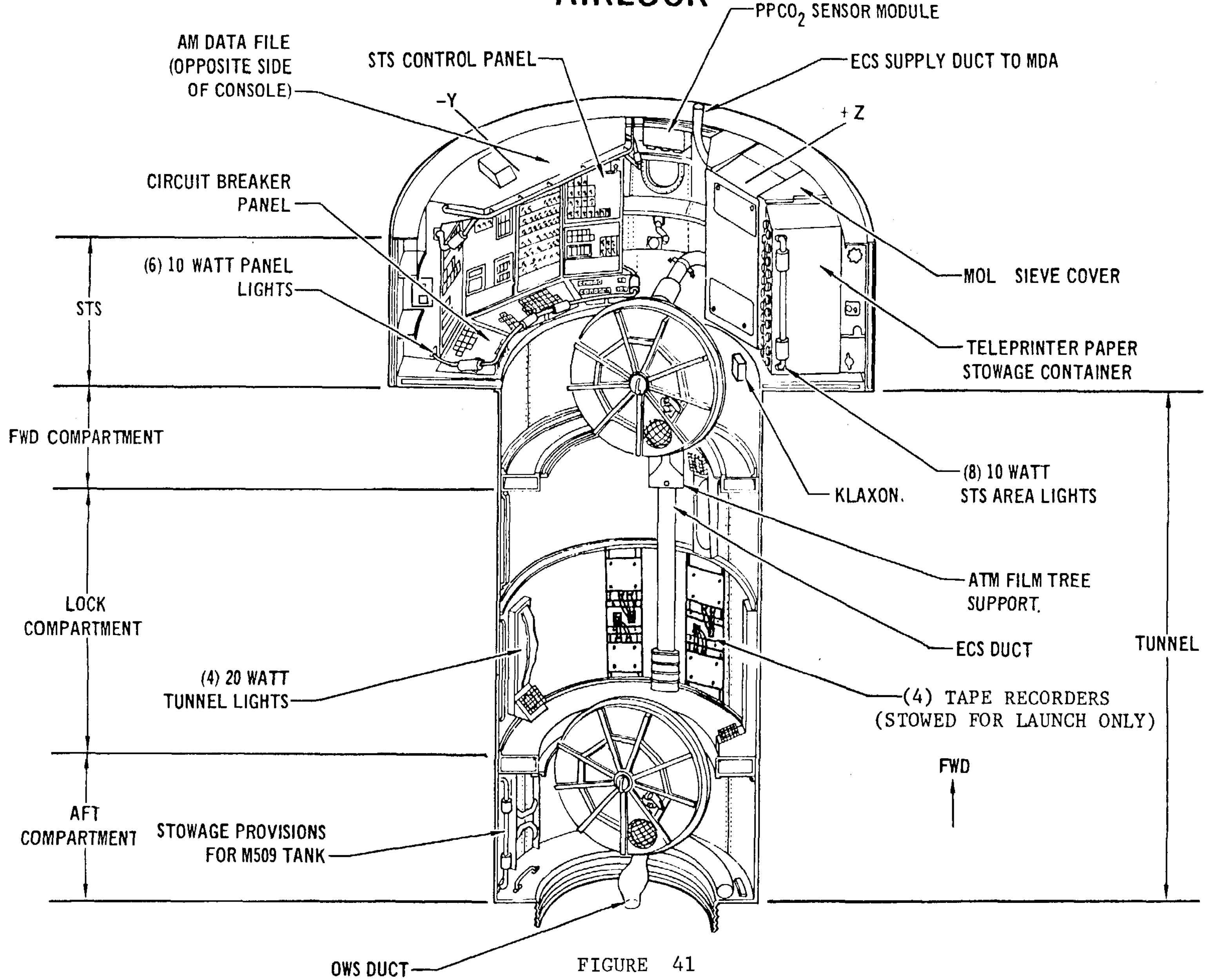


FIGURE 41

AIRLOCK

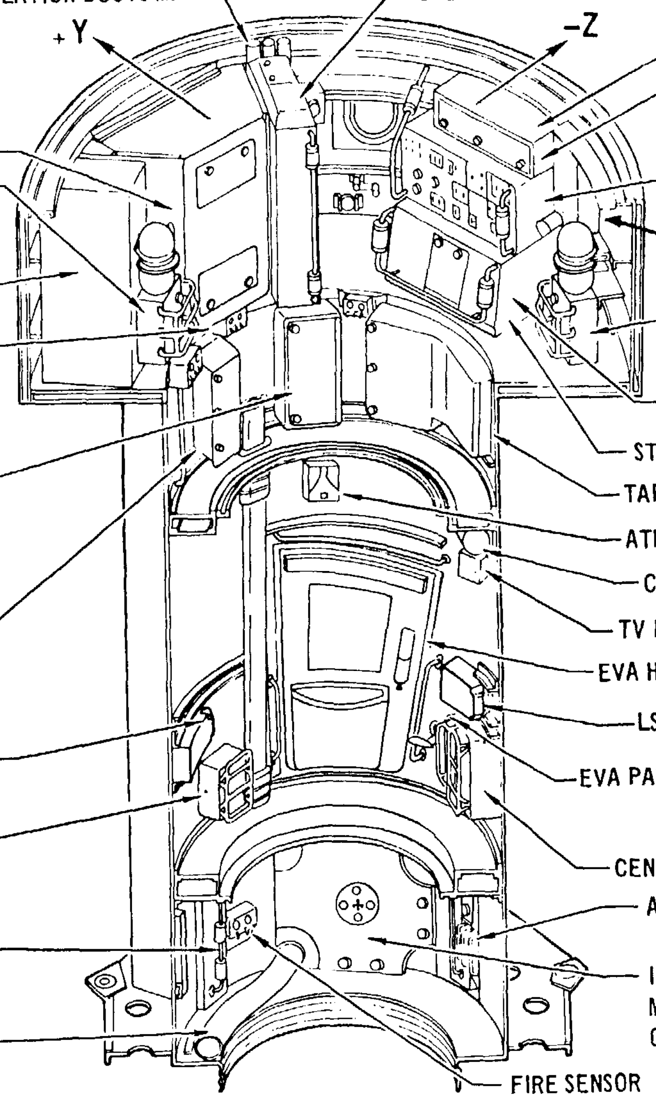


FIGURE 42

EXTERNAL EQUIPMENT

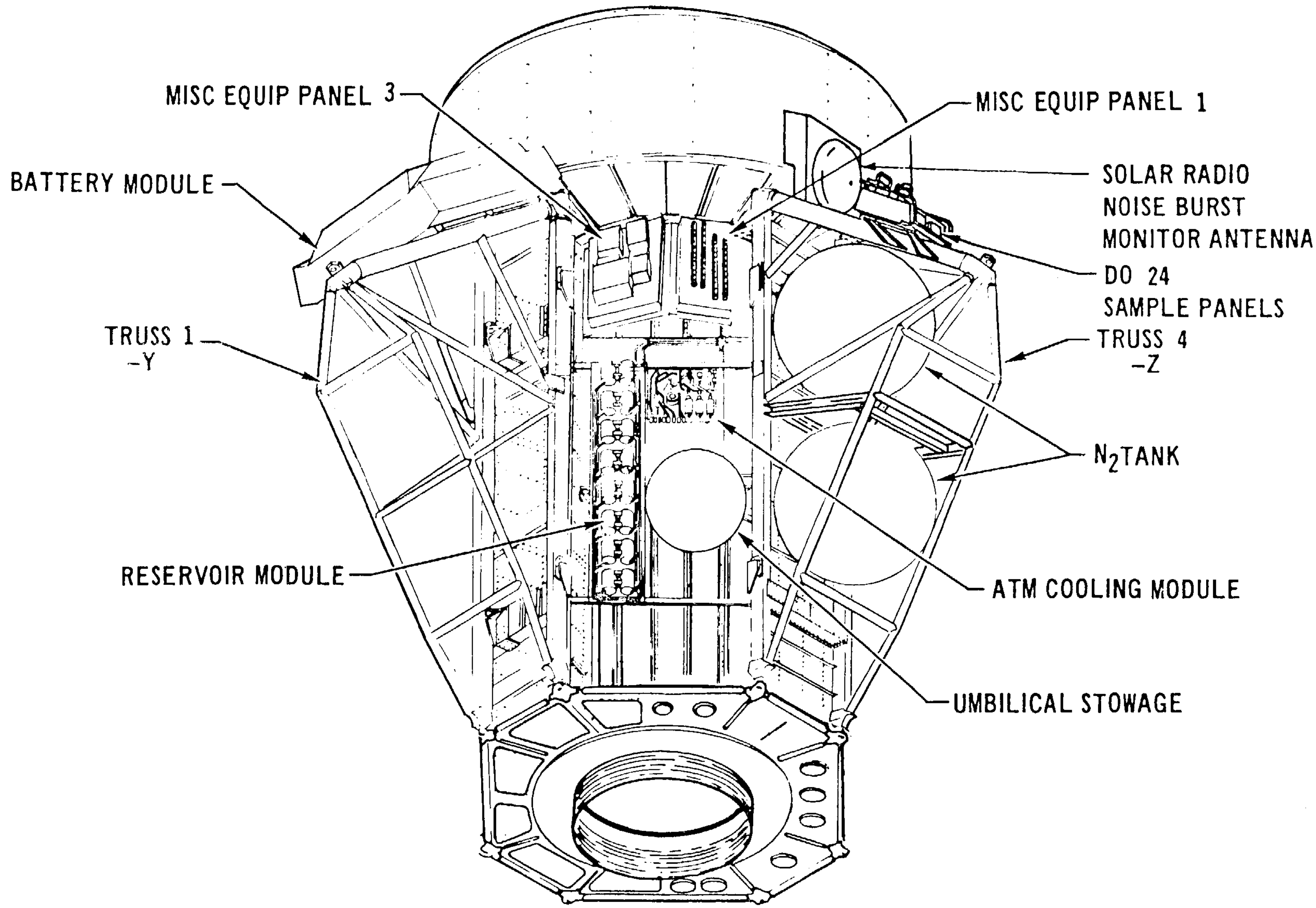


FIGURE 43

EXTERNAL EQUIPMENT

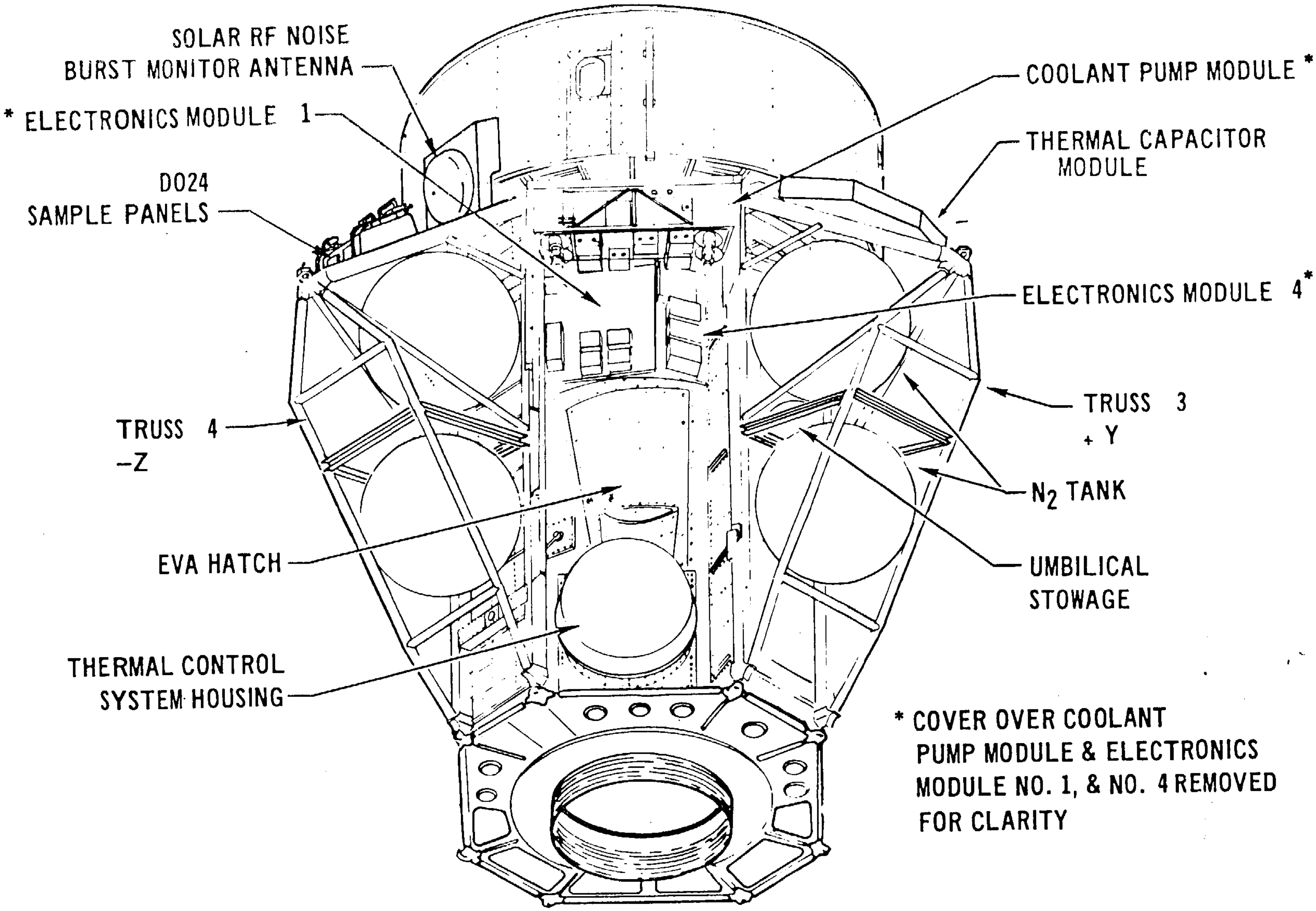


FIGURE 44

airlock module was designed to incorporate the Gemini hatch for EVA, Gemini latch assemblies on internal hatches, and Gemini ground support equipment as possible. As a result of all of these, NASA and the contractor were able to place more emphasis on hardware component assessment methods using similarity and analysis, and integrated testing between the MDA and AM. Vendor control of course was supported by the strength in related business activities as well. There were some difficulties encountered during the initiation of joint operational activities with MMC and MDAC-East and this was noted in the Panel's third annual report to the Administrator. The current posture is noted in the section "Response to the Preliminary Skylab Report."

Technical Implementation

The material discussed here was derived from Panel and staff attendance at the airlock modules DCR's and SAR's and the SOCAR.

Structures subsystem. - The basic structure is welded aluminum and consists of three sections: the structure transition section (STS), the tunnel, and the trusses. Added to these are the fixed airlock shroud and the deployment assembly for the ATM. The enclosed volume for the STS is 279 cubic feet and for the tunnel 345 cubic feet. A metallic convolute flexible bellows (42.5 in. internal diameter and 13 in. long) joins the AM to the OWS. This bellows provides continuity of the pressurized passageway between the AM and OWS. The bellows material is 0.025-inch aluminum. A fluorocarbon coating on the inside surface provides further pressure sealing capability. There are four ports provided for crew and experiment use. Other significant structural components include the EVA hatch, meteoroid protection, radiators, high pressure gas bottles and their attachments, and the various mechanisms used to activate and support AM operations.

The structural/mechanical aspects of the AM appear to have been carried through from design, fabrication, and test in a manner which resulted in a few problems of significance. Normal developmental problems occurred as they have for all the other Skylab modules.

Airlock penetrations, the ATM deployment assembly, and the meteoroid shield/radiator were areas of specific interest to the Panel.

Airlock penetrations include major areas such as hatches, windows, and pressure equalization valves in internal hatch doors, and the interface surfaces between the AM and the OWS and MDA. Particular attention has been given to maintaining leakage rates at or below the required level. This is because of the significance of the AM in meeting EVA pressurization demands and the number of windows. Hatch seals were a problem at the beginning. They have been redesigned and retested with new material and appear to have successfully completed all qualification testing. It might be well to mention here that the material used by the AM for hatch seals is now different than that used in the MDA seals. The windows as in the case of the OWS had venting provisions added to control the differential pressure in the cavity between panes. These were requalified successfully. These pressure/leak tests were completed during the past few months prior to the spacecraft acceptance reviews.

The ATM deployment assembly is a complex unit consisting of numerous "mechanisms" over and above the basic truss structure. Because of its criticality the deployment assembly was designed so that a single mechanical failure would not impair its operation. A significant point of interest is that the deployment reels are the only life cycle critical items on the AM. However, it is not expected that ground usage will require changeout. The pyro components are, of course, shelf-life critical; pyro appears to be no problem for the AM based on data supplied to the Panel. Rotary joint corrosion was considered the major possibility of a "hang-up" in deployment.

At NASA's request MDAC-East was to establish, through analysis and test, the minimum margin for deployment when one or both trunnion bearings are jammed or "frozen," forcing slippage of the entire bearing unit. They were to determine the maximum ecentricity of the latch engagement resulting from a single "frozen" bearing slipping as a unit. Based on analysis it was projected that no adverse impact would occur. Tests were initiated to verify the analysis. The closure of this will be noted in the next report.

The structures and mechanical system performance summary as presented at the formal DCR is shown in table XIV. The factor of safety appears to exceed the specification.

Environmental/thermal control system. - This system consists of gas supply, atmospheric control, thermal control, ATM control and display and EREP cooling, suit cooling, and purge. The ECS/TCS is shown schematically in figure 45. The 8-month endurance test which was completed in April 1972 provided much of the substantiation for the total system. Prior to examining the material presented at Panel reviews and at those programmatic reviews attended by the Panel it is well to look briefly at the part that each of the subsystems plays in the total ECS/TCS.

The gas supply provides about 5600 pounds of oxygen and 15 pounds of nitrogen from the high pressure bottles. This maintains a 74 to 26 percent oxygen to nitrogen atmosphere at a nominal pressure of 5 psia. The atmospheric control system provides moisture control, carbon dioxide and odor control, ventilation, and cabin gas cooling. Moisture is removed from the atmosphere by condensing heat exchangers and molecular sieve systems. They also remove CO_2 and odors. Ventilation is provided by GFE fans and condensing heat exchanger compressors. The thermal control consists of active and passive elements in much the same fashion as found on the other cluster modules. Active equipment consists of suit cooling heat exchangers, condensing head exchangers, cabin heat exchangers, and an oxygen exchanger. Equipment cooled by coldplates includes tape

ENVIRONMENTAL CONTROL INTERFACE

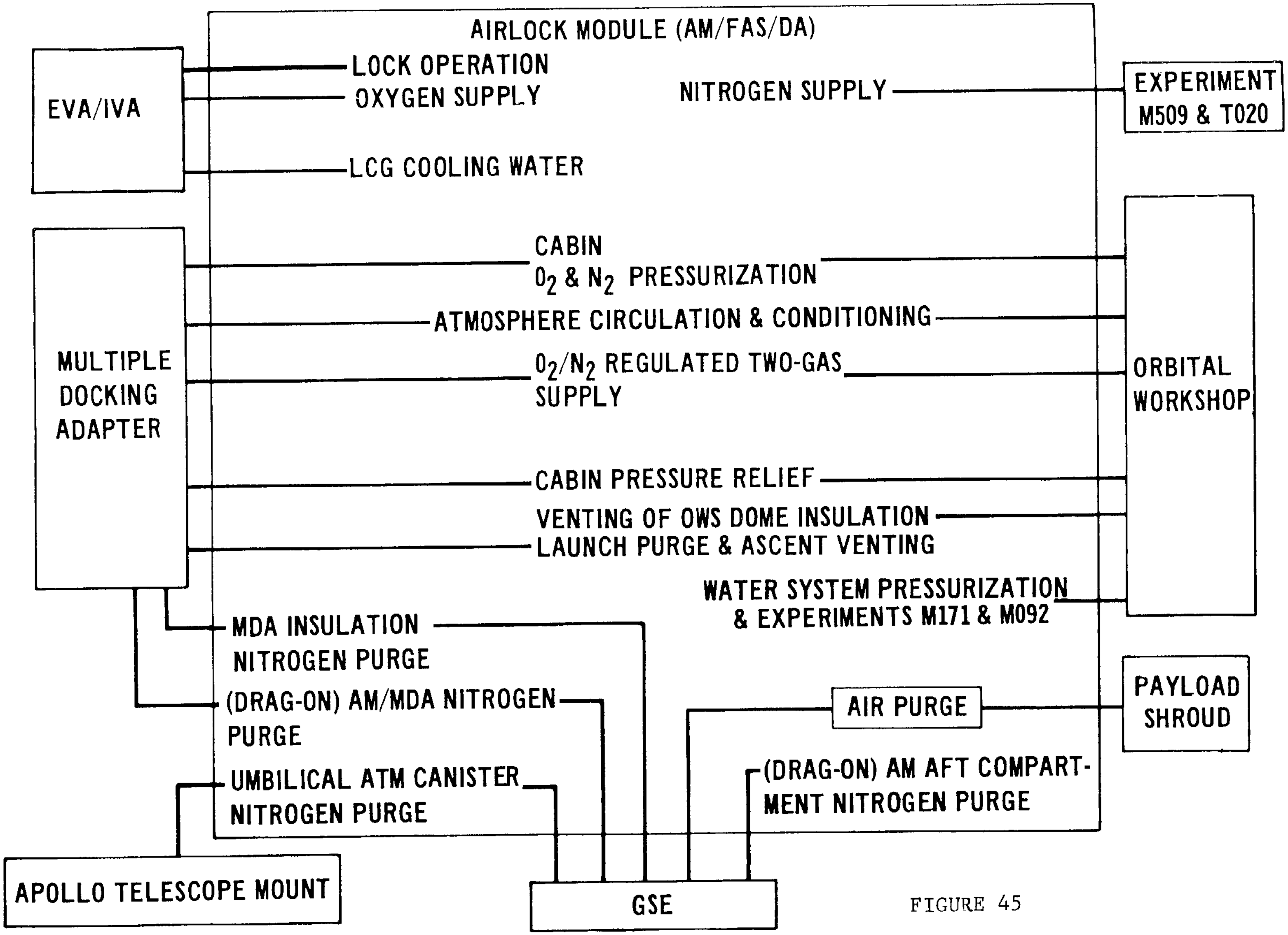


FIGURE 45

recorders, C&D panels, battery modules, EREP components, and electronic modules. Two separate coolant loops are provided for redundancy. The passive portion of the system includes thermal coatings, insulation, and curtains acting as insulation. The suit cooling system provides astronaut cooling during EVA and IVA by circulating temperature controlled water through suit umbilicals to the liquid cooled garments. Ground cooling and purge are provided by GSE cooling loops interfacing with in-flight heat exchangers and nitrogen purse gas introduced through a special fitting in the aft portion of the AM tunnel.

The test also included the related electrical communication and instrumentation components. The basic purpose of the test was to validate that the components had the endurance to function properly for a complete mission. The test system was designed to load the components under expected flight conditions. Factory and CSC procedures are the same.

The data were provided to the Panel on the development, qualification, and endurance tests at the component, module, and subsystem levels. These data indicated the system could meet the requirements. There are, however, a number of items remaining open from the test program and studies conducted by NASA and the contractor. The most significant items are noted here:

1. Thermal capacitor. The primary AM hardware problem has been due to a required redesign of the liquid cooling system thermal capacitor. The redesign was necessitated by structural problems caused by phase change wax expansion. A new capacitor was designed and built. It is undergoing qualification test with an estimated completion date of December 1, 1972.

2. Condensing heat exchanger separater plates. It appears that the separater plate assemblies started gas leakage long before they were expected. Redesign and retest were initiated. The qualification test was completed. A 140-day life test is being conducted with expected completion on December 27, 1972.

3. EVA suit coolant loop pumps. During acceptance tests all four pumps failed to start after 1 week dormancy in coolant loop fluid. Apparently interaction between loop materials and additives caused formation of nickel orthophosphate octalhydrate deposits (K_2HPO_4 with nickel from heat exchanger). These deposits prevented pump startup. NASA and contractor organizations are intensely investigating this problem. There is hope for a test start on December 15, 1972.

4. Condensate dump system. This was mentioned in the section of the report covering the OWS. It is, though, an AM problem. The problem is indicated as failure to dump condensate formed in the condensation heat exchangers into the OWS waste tank. This is due either to freezing in the exit port to one waste tank or entrapment of air in the water line. Design changes are still in process and testing is scheduled for completion around January 1973.

To better understand and predict ECS/TCS performance additional studies have been instituted. These include (1) definition of the coolant loop performance, (2) recommendations on flight procedures when providing water cooling for the three crewmen during EVA for various combinations of water loop operation, and (3) assessment of the impact of the rescue mission on AM ECS/TCS. There appeared to be some discussion concerning the GSE interface data needs and their control between KSC and MSFC. The extent of this question and its resolution are not known. The question of how long the crew can use the cluster if the ECS fails is one that must be answered in contingency planning. Such contingency planning will be reviewed further in the next report.

The successful completion of all component-level qualifications testing coupled with successful completion of the system level testing should provide the necessary confidence in the AM environment and thermal control systems.

EVA/IVA subsystem crew hardware. - The Skylab EVA currently involves all three crewmen for periods of up to 3 hours. During the first visit, 28-day occupancy, one EVA is planned. The second and third visits require 3 and 2 EVA missions, respectively. It is our understanding that there are no contingency EVA's planned at this time although they are under consideration.

The EVA hardware includes such items as an exterior workstation, lighting, film transfer mechanisms, handrails, oxygen, electrical power, and communications for the three suited crewmen. The Panel did not examine EVA hardware in any detail other than to assure that the cognizant organizations were delving into these systems to root out the problems and resolve them. There appear to be no major problems, and those items that were still open at the time of the formal DCR did not seem to be significant (i.e., EVA foot restraint functional tests and requalification of the film transfer boom device).

Electrical power system. - The EPS conditions power received from a solar array, mounted on the OWS, charges the nickel-cadmium batteries and supplies load requirements. During orbital dark periods, power is supplied to the load from the nickel-cadmium batteries. System output voltage is adjustable for proper load sharing periods of parallel operation with other cluster power sources. AM power system normally operates in parallel with the ATM power system to satisfy cluster power requirements.

The electrical power distribution system is comprised of positive isolated buses with a common return. The negative bus is tied to the vehicle structure at only one point (single point ground). The isolated buses may be tied together through two circuit breakers by the crew when necessary. Overvoltage protection is supplied by bus shunt regulators. The electrical power system protection is further discussed in the CLUSTER FAULT CURRENT PROTECTION and SNEAK CIRCUIT ANALYSIS sections. The EPS is shown in figure 46.

Because of prior spaceflight history and the fact that EPS is generally accepted as the major, if not only, ignition source available on board the Skylab vehicles, the Panel

SKYLAB ELECTRICAL POWER DISTRIBUTION

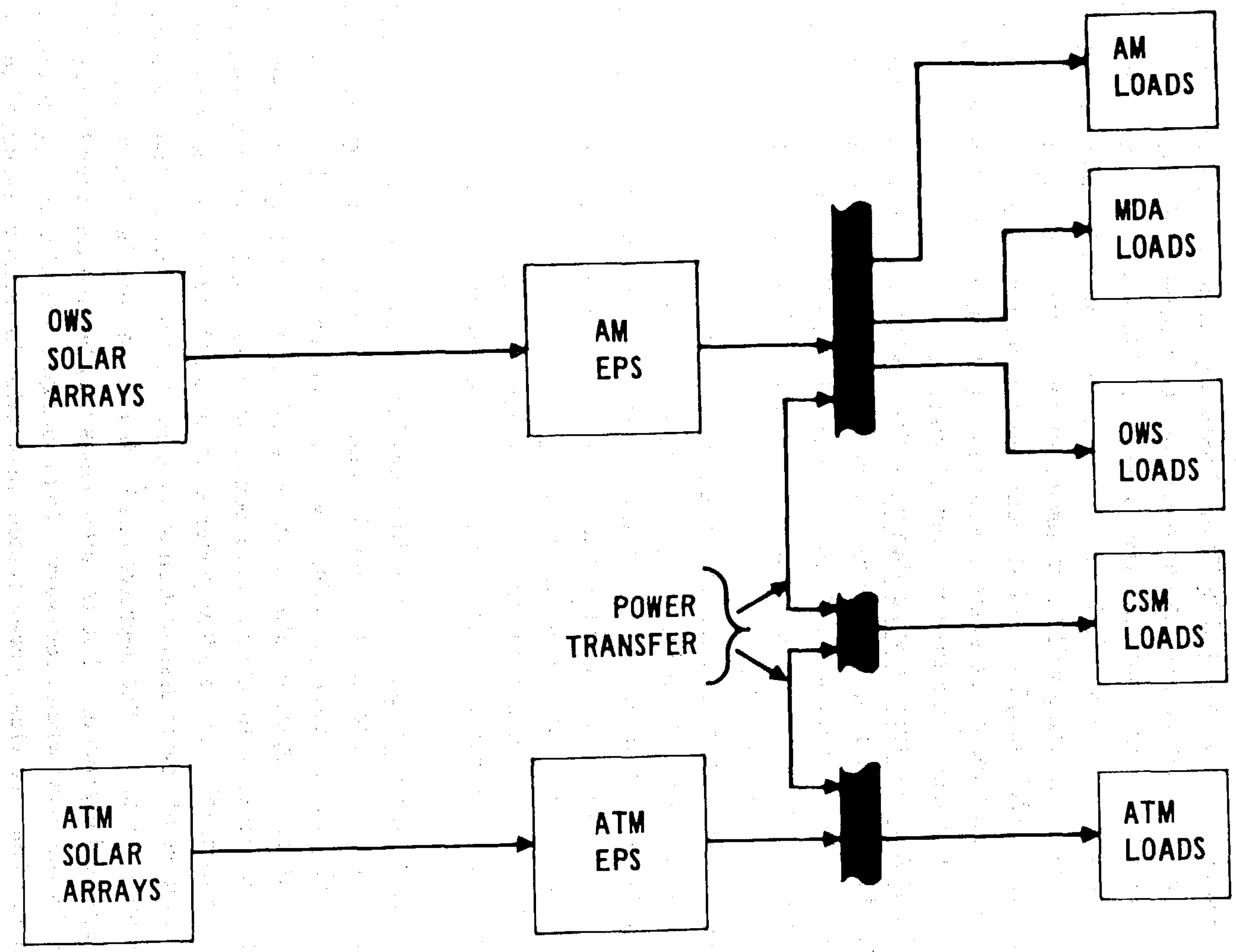


FIGURE 46

exerted additional effort in examining this system. The Panel specifically was interested in the wiring harness design and installation, the system tests and their results, and the FMEA and SFP analyses.

The wiring design, fabrication, and installation were watched very closely by not only the contractor but NASA as well. It is pertinent to point out unique fabrication techniques used as well as important details which point up the extra care taken. This takes the form of a tabulation, but it will, no doubt, increase the readers confidence in the EPS:

1. During fabrication the harnesses were "layed-in" rather than fed through the module. This reduced installation time essentially eliminated wire damage due to scuffing and cutting, avoided "captive" wire harness problems, and allowed access for inspections.

2. Redundant wiring through separate routing paths was used to ensure that damage which may occur to one line is not likely to occur to the other.

3. Where connectors were involved sufficient wire slack was left to effect easy equipment removal. Connector clearances were made sufficient to preclude the need for special removal tools. Adjacent connector interchangeability was avoided wherever possible.

4. Insulation and buffering provided the following:
   (a) A structural insulation barrier for unprotected power feeders
   (b) 360° fiberglass reinforced silicon or fluorel wedge-type cushion clamps
   (c) Protected positive terminal strips with nylon dome nuts on terminal studs and molded potting overall
   (d) Protection of interior wiring not behind enclosed panels by polyimide, aluminum, and NBG convolute covers

5. Special wire bundle restraint methods control wire runs and possibility of damage.

The AM went through an exhaustive series of tests: development tests, qualification tests, spacecraft acceptance tests, supplier hardware acceptance tests, and special tests to verify specific items of concern. Only the nickel cadmium battery life cycle qualification test is incomplete. Its purpose is to requalify the redesign of the cells. The test was initiated October 15, 1972.

Caution and warning system. - Various aspects of this system have been covered under other sections of this report. The important point here is that the AM contains the chief center or master unit for the cluster C&W system. This system is shown schematically in figure 47.

During testing the rapid ΔP alarm was activated several times while the vehicle was being illuminated with radiofrequency energy from the radiation simulator system. This problem was resolved by replacing the existing wire bundle tied to the ΔP sensor

AM CAUTION AND WARNING SUBSYSTEM

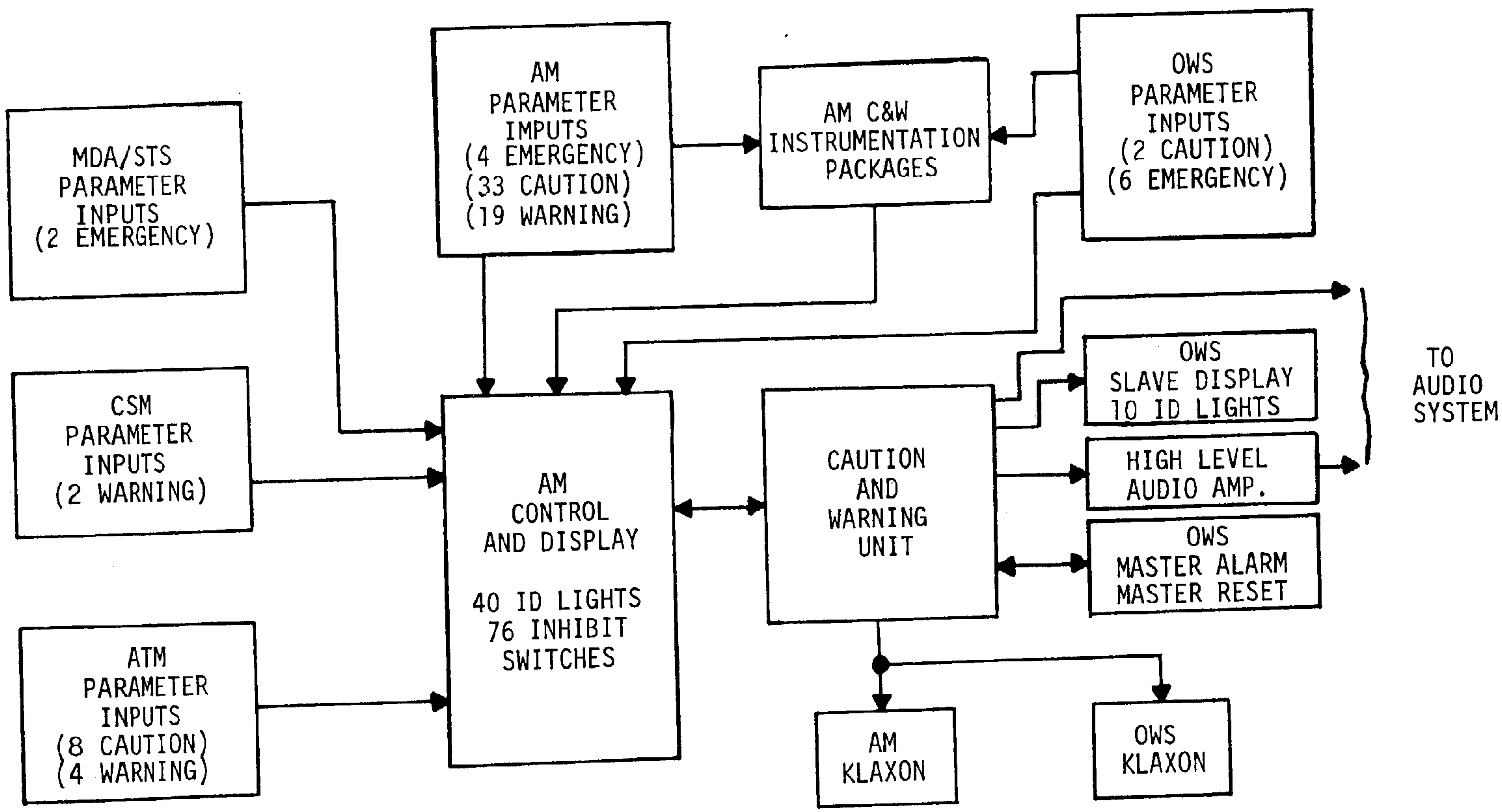


FIGURE 47

with a new cable. It is double shielded with ferrite beads installed on each wire within the cable.

The C&W system monitors fire and rate of pressure drop as well as bus voltages throughout the cluster, critical temperatures, partial pressure of oxygen, cluster attitude, etc. From the material reviewed by the Panel this system appears to be in good shape. The controls exercised by management and technical personnel indicate that this confidence is well placed. A further check of this system will occur during end-to-end testing at KSC.

Crew equipment. - This system consists of control and displays, mobility aids, lighting, stowage, communications and utility power outlets, and in-flight maintenance equipment. Essentially all of the problems identified in the SOCAR, DCR, and SAR have been closed or plan developed to achieve proper resolution. In the area of instrumentation and communications there are numerous qualification status reports still awaiting completion and approval by NASA. These should be accomplished as quickly as possible to assure proper documentation is available where and when it is needed. The same problem appears to exist with respect to a number of I&C intercenter ICS's. Another item to be closed out at KSC in February 1973 is the AM data recorders since acceptance testing was not complete at the time of AM turnover. A system performance summary chart used at the DCR provides additional data on the AM data subsystem (table XV).

During altitude chamber testing the Mosite packing material used in stowage containers swelled and contracted due to entrapped gas in the interstices of the Mosite. This material problem is applicable to both the AM and MDA. It is discussed more fully in the CLUSTER MATERIALS section. The problem is being resolved by changing material and reworking current locations to preclude interference between Mosite and hardware.

The in-flight maintenance program was reviewed in detail during the SOCAR activities. There were three significant results from the in-flight maintenance team report:

A. At the present time the IFM activity integrates all onboard tools to ensure availability and to preclude duplication. However, there is no formal method for cluster tool requirements, other than for in-flight maintenance tasks, to be transmitted to personnel involved with IFM. Consequently, the SOCAR Team Chairman recommends that action be taken to have the IFM program expanded to include activation, deactivation and operational tasks which involve tools, spares and/or servicing. He will also ensure that extravehicular mobility unit (EMU) and microbial contamination control tasks are adequately covered in the operational documentation.

B. Level II CCB approval of new IFM tasks requires too much time. A crew IFM procedure, in addition to other task data, will be provided by module contractors. MSC will review the procedure and other task data and verify the task as necessary. This will reduce approval time, changes, and revisions later on in the program.

C. Many inconsistencies exist in IFM program documentation. These differences are primarily between the IFM baseline document (LS-005-003-2H) and the Operations Handbook.

The Panel, as a result of its review of data presented at the DCR's and SAR's, feels that these problems are well in hand and envisions few difficulties in the future.

Risk Assessment and the Management System

MDAC-East's management systems effectively used Mercury and Gemini experience. They also made efficient use of NASA and intracompany support.

MDAC-East has used a series of tools to assist in the identification and solution of technical problems in a manner much the same as other contractors. These tools include FMEA, design reviews, use of NASA alerts, continuous management review of designs and procedures for hazard identification and resolution, personnel motivation programs, test and development organizations, and tight vendor control. The result is our confidence in management and the flight systems.

MDAC-East used meetings of in-house and NASA personnel on a daily, weekly, and monthly basis to discuss status, problems, solutions by engineering, manufacturing, test, and management.

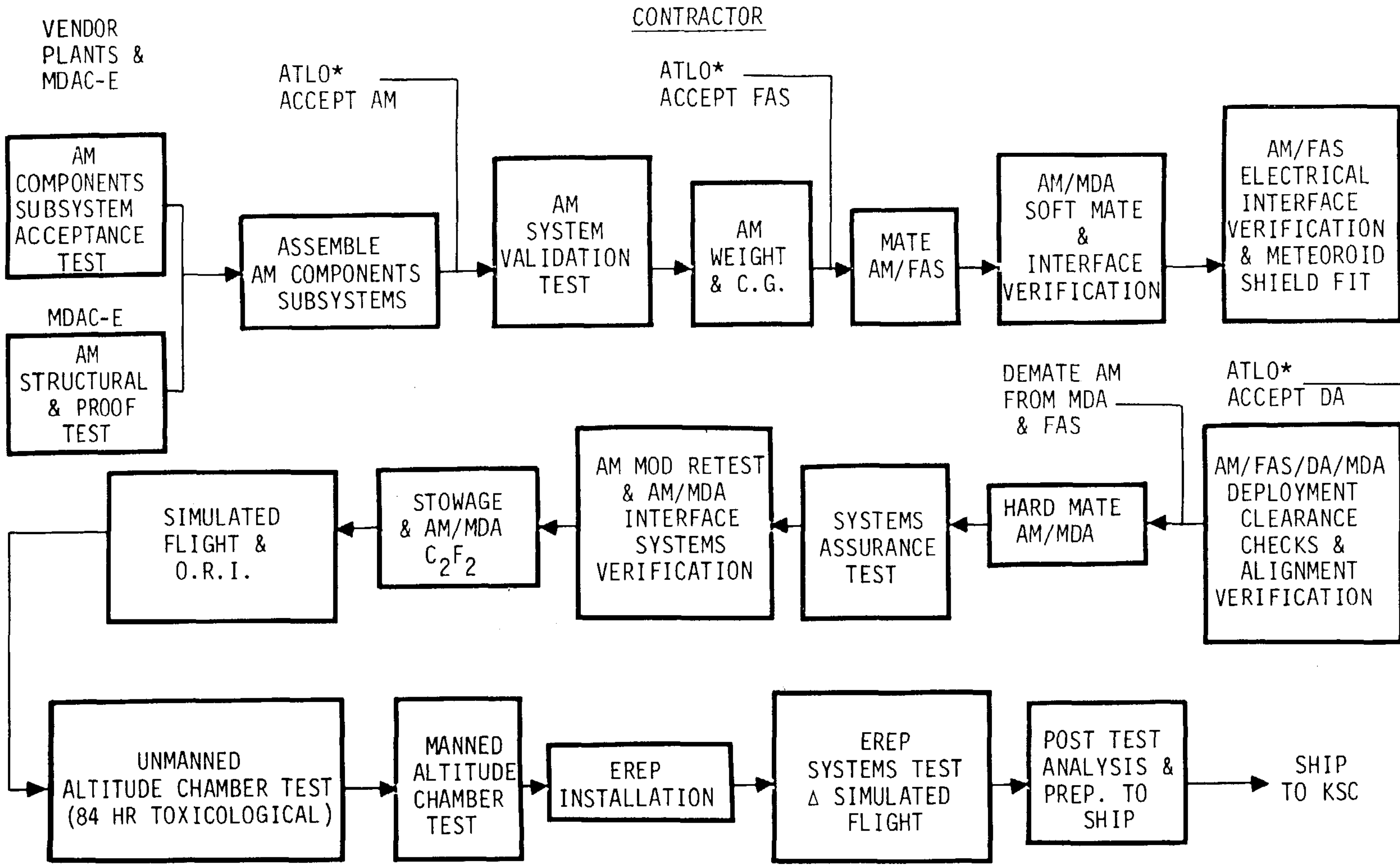
Test procedure formulation and actual test activity appears to have been closely coordinated with and monitored by NASA. Where anomalous conditions were encountered and corrected it again appears to have involved a high degree of coordination and information interchange with NASA. The test program is carried out at the factory and at the test site as shown in the schematics (figs. 48 and 49).

MDAC also conducted a self-assessment in terms of the findings and recommendations of the Centaur and Thor-Delta report. They noted the key personnel, including all engineers, have been given motivation and orientation lectures, and that NASA/MDAC motivation material is used to maintain continuous attention to this area. Vendors were furnished the same material. Vendor hardware penetration surveys concentrated on how the vendor personnel actually design, fabricate, test, and handle the hardware. As deficiencies were noted they were quickly examined and corrected to preclude further impact on the factory design, test, and fabrication. Internal AM reviews were structured to take into account ease of assembly based on the need to inspect and test.

To further understand and reduce the hazards on the AM, MSFC directed MDAC-East to expand the on-going AM and AM/GSE FMEA program to include the following failure modes: (1) relays and switches with respect to premature operation and failure to cease operation, (2) circuit breakers with regard to short to ground on unprotected side, and (3) connectors with regard to open and shorted pins. This expanded program resulted in

AIRLOCK MODULE

ACCEPTANCE TESTING



*ACCEPTANCE TEST AND LAUNCH OPERATIONS DIVISION

FIGURE 48

AM/MDA/FAS/DA/PS
ACCEPTANCE TESTING

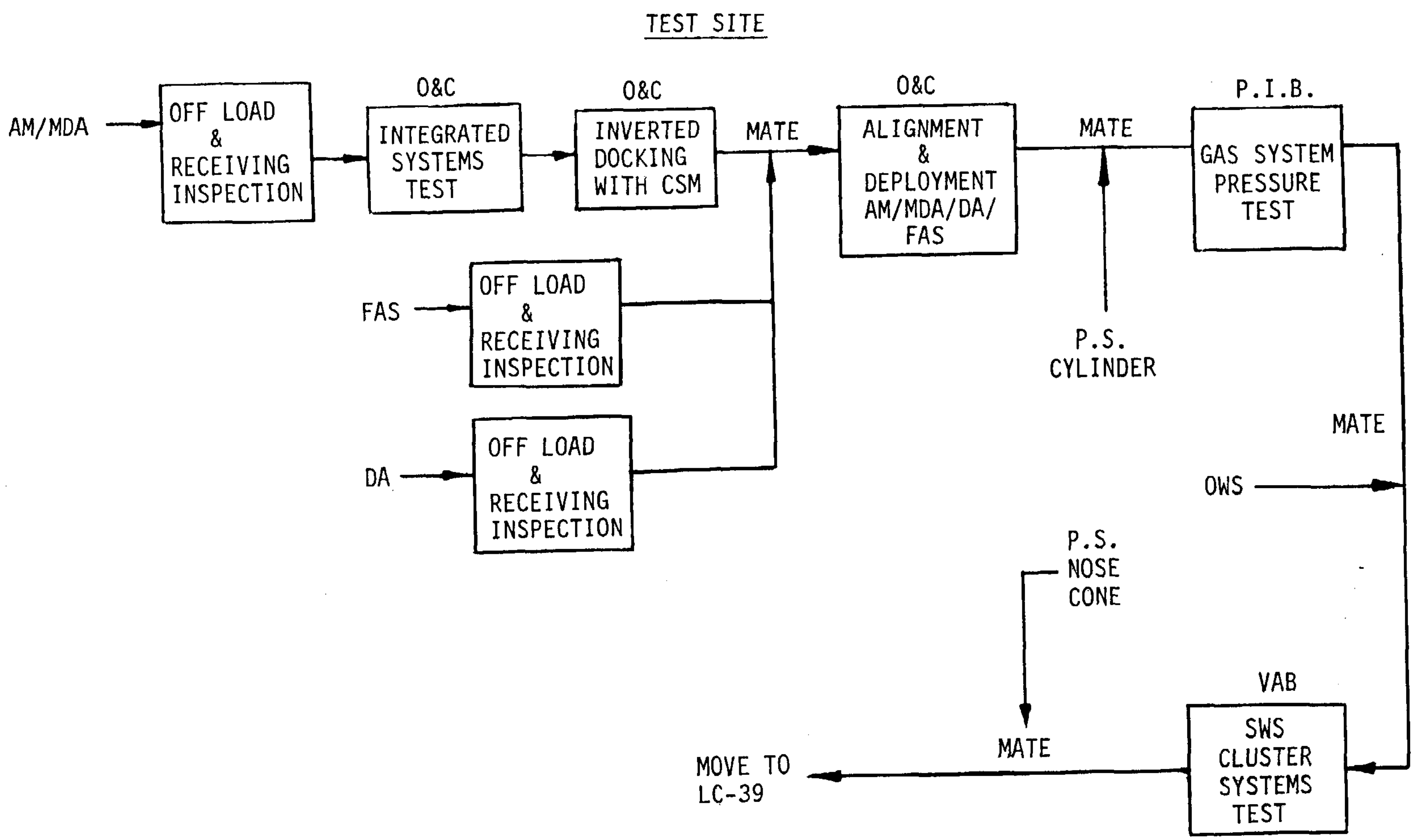


FIGURE 49

the evaluation of approximately 29,000 additional conditions of failure. Completion of this effort is expected by February 1973.

Meetings have been held periodically with Martin Marietta Corporation integration personnel and appropriate NASA personnel to resolve safety problems and noncompliance items encountered during system safety checklist analyses. As an example, special analyses were conducted to determine the flammability characteristics of flame propagation in the condensing heat exchanger and the molecular sieves modules.

The Panel asked about the high pressure gas system which carries nitrogen and oxygen into the onboard systems. It appears that the high pressures from the storage bottles surrounding the AM are carried to the basic AM structure (internal) before a pressure reduction valve system comes into play to reduce pressures to those needed. Prior experience has indicated that such pressure reductions should take place as close to the high pressure source as possible. If this is the case, the rationale for this design decision should be included in the SAR.

Inspection of the AM by the walk-through NASA group indicated that there were several instances of electrical cables in close proximity to sharp corners and edges and that some wiring was "squeezed" into containers and trays.

In summarizing the discussion of the AM systems the following open items are noted:

1. ATM deployment mechanism tests on jammed or "frozen" trunnion bearings
2. In the ECS/TCS -
   (a) Thermal capacitor requalification test
   (b) Condensing heat exchanger life tests
   (c) EVA suit coolant loop pump corrosion problem
   (d) Condensate dump system design change and retest in process
3. Nickel cadmium battery requalification test
4. Life test of the partial pressure oxygen transducer life test

The material presented to the Panel indicated an adequate AM management system. Again it is of the greatest importance to maintain the same high level of motivation and competence on the program as the AM moves through the test, checkout, and launch preparations period at the KSC.

MULTIPLE DOCKING ADAPTER

The multiple docking adapter (MDA) is the control center for Apollo telescope mount (ATM) and Earth resource experiment package (EREP) experiments. It is mounted on the forward end of the airlock module, and provides a docking post for the CSM's and a structural support to docked spacecraft. The MDA is a 10 1/2 foot diameter cylinder and is slightly over 17 feet long (see fig. 50).

The primary port for docking the CSM is axial and located at the forward end. The

MDA

HARDWARE ELEMENTS - EXTERIOR

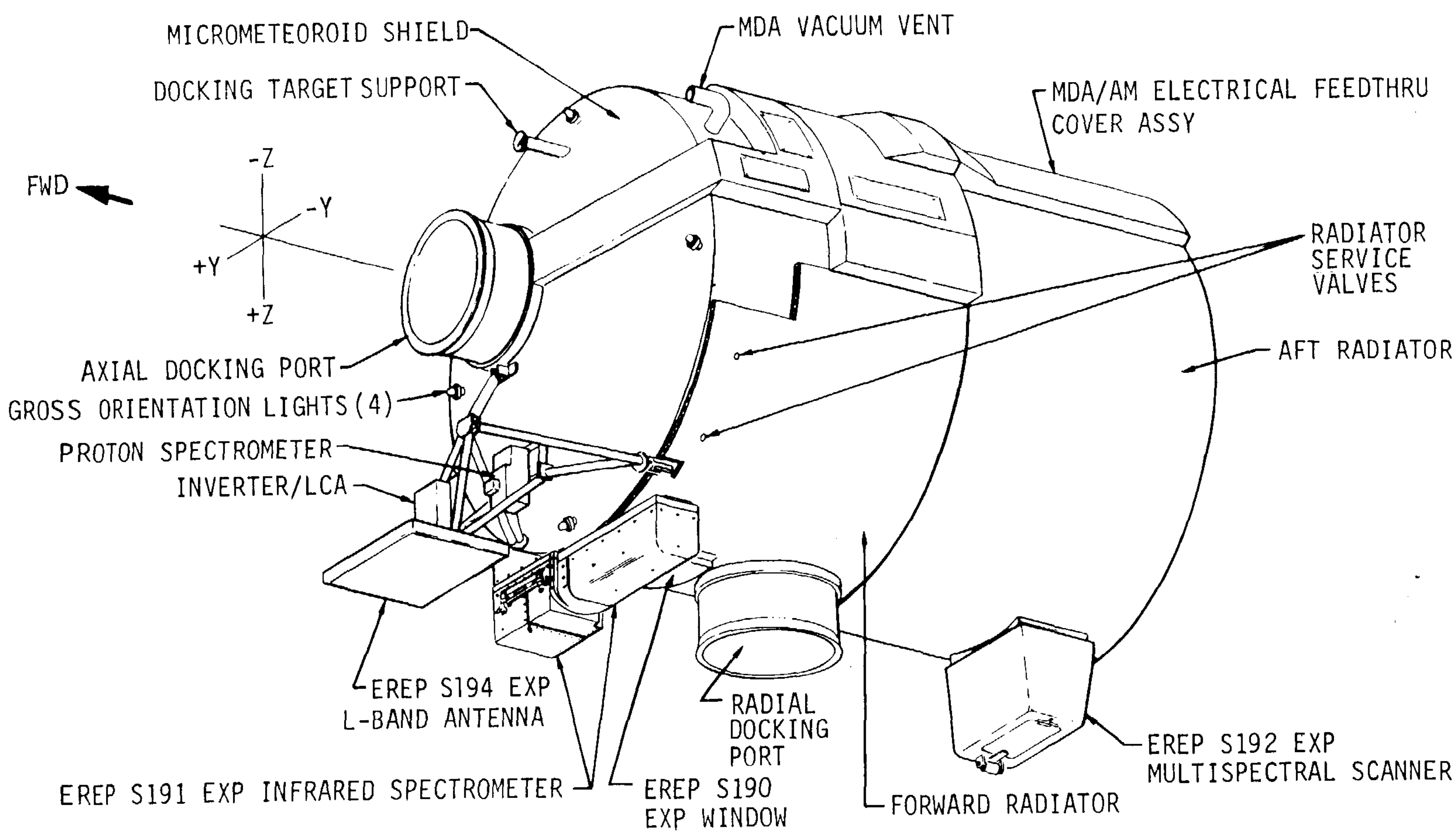


FIGURE 50

alternate port is located on the side of the module. Cameras and EREP sensors are located adjacent to the alternate docking port. Some look through a window in the wall, others actually protrude through the wall. Vaults are provided for storage of cameras and film for the ATM experiments. These vaults protect the film from the radiation environment experienced at orbiting altitudes.

The control and display console for the ATM is located in the rear of the module. It contains all the controls and instruments required for operation and observation of the ATM solar astronomy experiments. This control and display console also contains the instruments and controls for the ATM attitude control system and for the ATM electrical power system.

The MDA presented unique management challenges. It was initially designed and partially manufactured at Marshall. Then the utilization contractor in support of Marshall assumed responsibility to complete and equip the module. Finally, it was shipped to another contractor site for mating with his module and integrated testing. Thus, transfers of work and joint operating agreements had to be well defined. This is one illustration of the variety of contractual and operational situations in Skylab. That these arrangements were managed as well as they were speaks well for the contractor and NASA.

Management Aspects

The MMC-Denver did not have direct experience with management of manned space vehicles. However, they had substantial background in both manned (Gemini) and unmanned vehicles as well as manned spacecraft studies (Dynasoar, MOL). They have achieved a high degree of proficiency in carrying out their roles and responsibilities. In its review the Panel examined the pattern of problems encountered and the problem solving mechanisms. We also reviewed mechanisms to assure (1) senior management visibility of in-house operations, (2) assimilation and use of prior hazard knowledge and overall risk assessment experience, (3) quality assurance, (4) vendor control, and (5) intercontractor/NASA coordination. Activities to integrate the MDA into the cluster were of particular interest because of the contractors' overall integration role and the interfaces between the MDA and MSFC's Apollo telescope mount and the MSC Earth resources experiment package.

Special attention had been given to personnel responsibility, attitudes, and skills. MMC considers the PIE concept as one of the major contributors to goals of excellence in design, test, manufacturing, and change control. The PIE is a highly qualified, specialized engineer assigned by the program manager. He has the responsibility for a specific area of emphasis on a continuous basis. Specific areas of emphasis include subsystems, major components, test, materials and processes, etc. He has the responsibility for the technical integrity of all phases of design, development, fabrication, test, and operations. In his work of preventing, recognizing, and solving problems he provides upper levels of management with the required visibility for them to make adequate and sound decisions. Specific procedures were issued to cover the PIE concept and its implementation. From the material presented to the Panel it appears that this system has worked well and provides both vertical and horizontal control of the MDA program.

The training and certification program is much like that of other Skylab contractors and appears to be thorough and consistently implemented.

The results of the Centaur/Delta boards were reviewed in depth by the managers assigned to manufacturing, test, and quality. MMC made special efforts to contact specific members of the Centaur board who could be helpful in providing MMC with more detailed insight into the workmanship and management problems that might be applicable to their own program. It was apparent that MMC initiated steps to achieve improvements in their system wherever warranted. This willingness to accept the problems and solutions of others indicated an openness that most certainly would aid in achieving successful hardware.

In its early reviews of MMC, the Panel noted that the normal problems inherent in any large scale program were evidenced here, but that, like any of the other contractors they were aware of them and resolving them as quickly as possible. The fact that MMC was the system integration contractor provided them with greater visibility of the program and the on-going problems. This in turn permitted them to look into their own operations with more knowledge. On the whole, the management systems and their implementation at MMC appeared to be in good shape and provided further confidence that not only their own hardware but the integrated cluster hardware would more nearly meet its requirements.

The interfaces illustrate the depth of MMC's penetration into the program. These interfaces involve EREP support equipment, medical and scientific experiments, associated GSE, Skylab experiment GFE and ICD configuration management, mockups and training equipment, and engineering support.

To assure that adequate skills continue to be available, key personnel are identified by discipline and name for retention to provide failure/anomaly review and analysis, test site support, and mission support. Furthermore, MMC is involved in the logistic support area dealing with spares and repair depot efforts. Skylab postdelivery support covered the following four areas:

Medical and scientific experiments at MDAC-West	October 1971 through August 1972
EREP and scientific experiments at MMC and MDAC-East	June 1971 through August 1972
KSC experiment support	August 1972 through December 1973
Denver engineering support	Current through December 1973

Hardware Aspects

In the design of the MDA, as in the other Skylab modules, the use of prior manned space programs experience and hardware played a very prominent part. For example, the design specifications, materials data, cleanliness, and general safety criteria were derived from Apollo and Gemini programs. In the case of hardware the following items were used:

Fire extinguisher (Apollo)	Docking drogue (Apollo)
Connectors (Apollo)	Docking targets (Apollo)
Flex lines (Apollo)	4-port selector valves (Apollo)
Fans (Apollo)	ΔP gages (Apollo)
Equalization valve (Gemini)	Running lights (Gemini)

The experiments mounted in and on the MDA are covered in the EXPERIMENTS section of this report. The ATM C&D panel is covered under the APOLLO TELESCOPE MOUNT section of this report.

Throughout the design, fabrication, and testing of the MDA there has been crew participation. This close coordination and consultation has been most helpful in producing a vehicle to meet the hardware and crew requirements in an optimum manner.

Some of the program concerns noted in the January 1972 review by the Panel are still present in the program. This is particularly true of the amount of deferred work due to nonflight hardware used in place of flight equipment.

Structures

There have been no significant design changes to the basic structure since the critical design review. Items of structural interest which are indicative of the ability to meet and resolve problems include the L-band antenna truss, pressure hatches (axial and radial), windows, window covers, and stowage containers.

The MDA proof pressure and leak test indicated that the actual leakage rates were some 20 percent of the allowable (1.097 lb/day versus 5.280 lb/day). All of this occurs through the MDA shell and the axial tunnel with no unacceptable losses through the radial tunnel area. When tested with the AM in a combined mode at St. Louis the total leakage was less than 2.2 pounds per day at 5 psi differential for both modules.

Structural verification methods for the cluster state that "Hardware that has calculated factors of safety of 3.0 or above and those that are similar to previously tested and used hardware are to be verified by analysis only. Hardware designed with factors of safety below 3.0 shall be tested to demonstrate structural integrity." While the windows have calculated factors of safety in excess of 3.0 they were tested none the less because of their criticality.

The L-band antenna truss structure is not in itself a critical item. It does, however, support the inverter lighting control assembly which is controlled by both the critical and limited life listing. There is a constraint to installation. The truss cannot be installed on the MDA at the same time as the MDA handling fixture because they both attach to the same fitting. This becomes a matter to be covered by the handling and associated procedures documents to assure no inadvertant impact on this truss.

The removable hatches provided for each docking port are functionally interchangeable. Hatch handles are provided on both sides of each hatch so that a hatch can be manually opened or closed from either side of the hatch. A positive lock is provided on the hatch handle (CSM side) to preclude inadvertent actuation. This lock permits contingency mode operation of the hatch from inside the MDA. Each hatch contains delta pressure gages and a pressure equalization valve. The hatch lip rests on a silicone rubber seal to achieve a pressure tight closure. Due to problems with this seal material becoming sticky under test the material has been changed. It is currently undergoing long term qualification testing. Testing was initiated August 5, 1972, with completion set for April 1973. Interim inspections will be made of the seal material in September, November, and early April (1973) to ascertain its state. This will provide time if necessary to institute corrective measures. It is interesting to note that the seal materials used by MMC and MDAC-East are not the same. These hatches because of their criticality have received a good deal of emphasis from both the design and proofing standpoints.

The Panel examined the glass and window designs in the MDA. Currently the S190 safety shield is undergoing delta qualification testing as a result of design changes made to meet leak rate requirements. Estimated completion date is December 1972. There was an ECP in process to make the safety shield (which is a tempered glass) a complete structural backup for S190 window. The status of this ECP is to be noted in the next report. If this ECP were approved the resultant changes would most likely require some form of delta qualification and perhaps other associated documentation changes.

Environmental/Thermal Control Systems

The MDA uses the active ECS and TCS of the airlock module. The MDA contains its own passive system along with heaters as required. The passive thermal system consists of insulation blankets, paints, and coatings. The active system includes ducting and fans to circulate the atmosphere, heaters and associated thermostats, and coolant loops for the ATM C&D console and the EREP water loop and MDA radiator. The environmental control system consists of vent valves, equilization valves, mufflers, ducting, diffusers, and the like. Problems in this area have in general involved the ATM C&D and the EREP equipments. The basic MDA ECS/TCS hardware and test program appeared to offer few problems. The SOCAR determined that some minor hardware and documentation discrepancies existed. To our knowledge they have all been resolved. There were however some cases where flow tests were not conducted and the test deviation accepted on an analytical base. Typical were the flow and pressure drop test of ATM/EREP coolant system. The SOCAR indicated that the only discrepancies were associated with the valves and ΔP gage. This indicated few concerns here.

Electrical Power System and Caution and Warning

The MDA electrical system interconnects all electrical hardware between CSM/AM/ATM and other MDA loads. There are some 40,000 feet of wire with approximately 8,000 connections. As in the case of the other modules the wiring, when not conducted external to the manned areas, is covered in sleeves and trays that eliminate to the greatest extent possible proximity of flammables and ignition sources and propagation paths. Figure 51 is a simplified schematic of the cluster EPS. Of interest here is the relative dearth of equipment in the MDA in comparison to other modules. There appeared to be few areas of concern in this EPS and all are indicated to be closed.

The fire detection system in the MDA is comprised of two ultraviolet fire sensors (identical to those used throughout the cluster) and one fire sensor control panel. No anomalies were apparent in this system during the various phases of the acceptance review cycle. Any SOCAR actions have been closed. MMC's attention to the actions taken by MDAC-East, MDAC-West in their C&W systems seems to have paid dividends in their MDA efforts.

SIMPLIFIED DIAGRAM OF THE
ELECTRICAL POWER SYSTEM

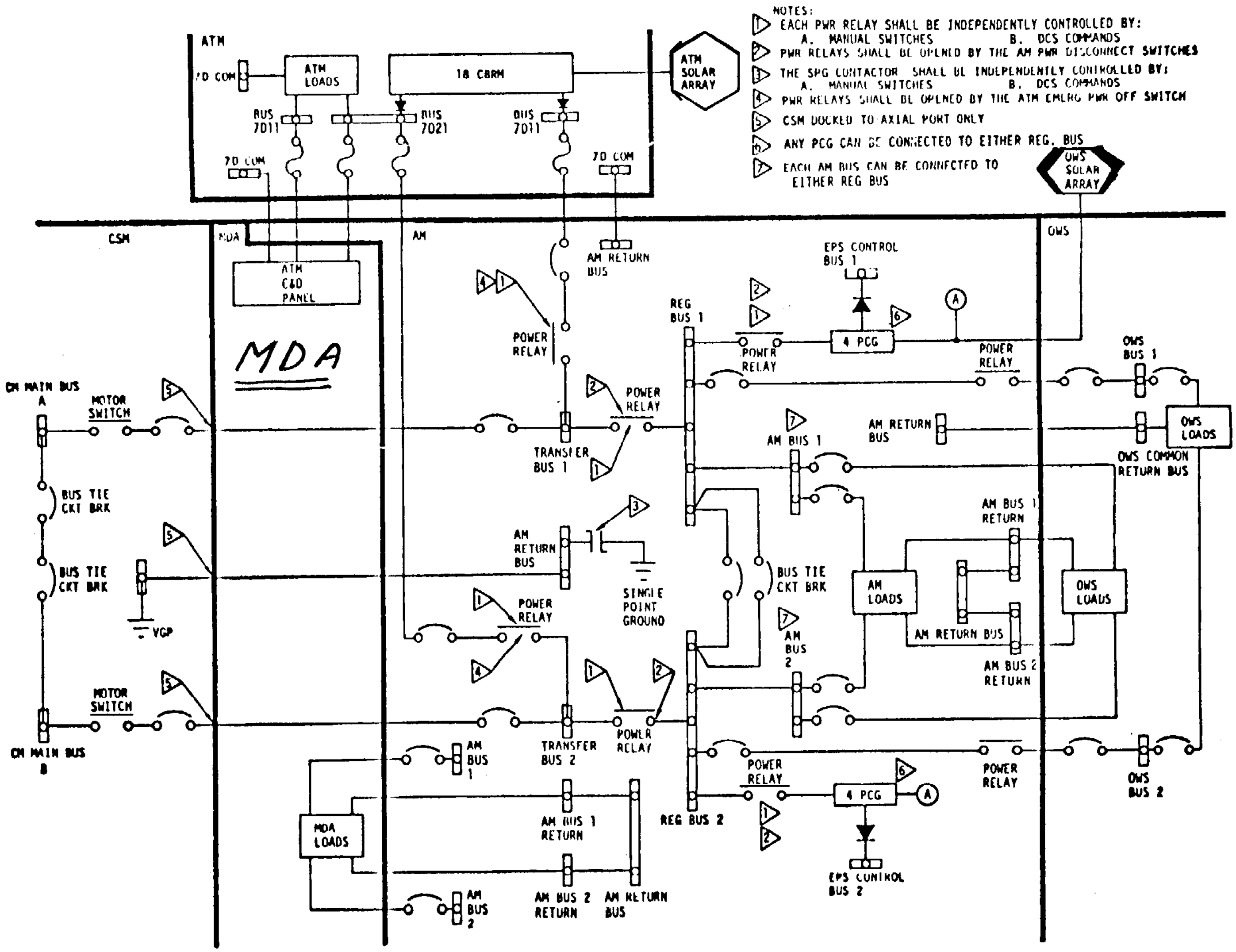


FIGURE 51

Instrumentation and Communications

The instrumentation system includes 89 measurements for temperature, hardware and experiments, and internal pressure. The communication system includes speaker intercoms, headsets, voice down-link via the CSM, and television input station and adjunct equipments. The MDA provides for all cluster television input stations. It includes a television video switch which permits selection capability in the television system and couples the video signal to the FM S-band transmitter in the CSM. In addition, it signals conditions and amplifies the ATM signals. Because of these multiple interfaces the interface control documentation system is most important. There were a number of open PIRN's to the basic ICD's. These should be closed as quickly as possible to preclude problems at the KSC during test and checkout operations. The history of the television systems, both on the Skylab program and prior manned/unmanned programs, indicates that this area requires a special effort on the part of management to assure that all will be in readiness by launch time.

Crew Equipment System

There are stowage areas using the Mosite material which has been discussed elsewhere. Repair materials and in-flight maintenance tools are also found in the MDA. One problem that still exists is the inverter/lighting control assembly. It generates noise at a level which appears to disturb the crew. The status of this problem will be noted in the next report. Test activites at KSC appear routine except for the evaluation of new mods to the axial hatch. This requires a crew test with MDA in the horizontal position.

Ground Support Equipment

The GSE, including that supplied by NASA, has been used during the process of testing the MDA at both Denver and St. Louis. There are a few significant items of note which should probably be resolved prior to extensive testing at KSC. These involve the Skylab television test set, an electronic test set (GFP), and data quick look system and fit checks. There have been no indications that the GSE has over-exercised the flight hardware during the testing to date.

Management and Risk Assessment

While there were no doubt "growing pains" and learning experiences the quality of the MDA basic hardware reflects well on the individual skill, dedication, and thoroughness of management. A characteristic of the MMC efforts is the early and strong partici-

MDA

FLIGHT ARTICLE FLOW DIAGRAM

KSC CHECKOUT OPERATIONS

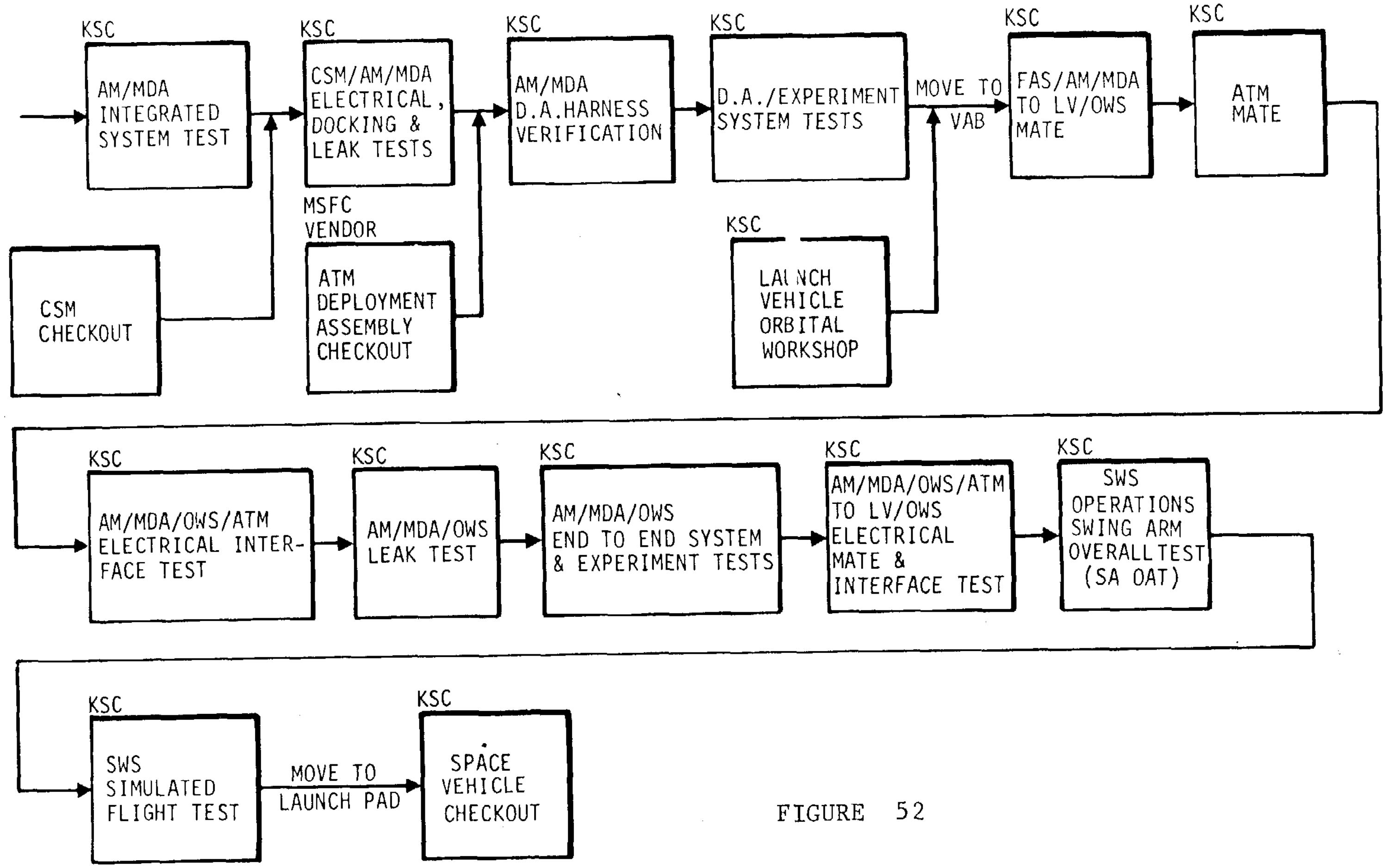


FIGURE 52

pation of the flight operations people in the hardware development program, again due in part to the integration working groups.

The MDA is expected to progress through its KSC cycle in the manner shown in figure 52. The open items noted in the preceeding discussion indicate no particular problems of significance should be expected during the KSC period. The experiments contained within the MDA are not a part of this discussion but are handled separately in the EXPERIMENTS section of this report.

PAYLOAD SHROUD

The payload shroud (PS) is designed to provide an environmental shield during the final stage of assembly/checkout and launch. It is also an aerodynamic fairing for launch and boost phases. Finally, it provides structural support to the Apollo telescope mount during prelaunch, launch, and boost phases.

The PS separates on command into four discrete segments. Radial velocities are sufficient to prevent recontact with the payload. Separation is effected through segment joints containing an explosive/bellows linear thrusting device located along the longitudinal segment separation lines. The shroud is unlatched prior to separation by explosive operated latch actuators. These are located at the segment joints for structural continuity. Separation is further aided by the use of tension cleats and bolts which fasten the lower end of the PS to the fixed airlock shroud.

This unit is handled in somewhat different fashion than other modules contracted to the MDAC-West and East divisions. The airlock payload shroud is contracted to MDAC-East as part of the airlock program. However, the shroud was manufactured by the MDAC-West special space programs office. This arrangement has not hampered the development and interface efforts in any way.

The general configuration of the PS is a double angle nose cone mounted on a 260-inch diameter cylindrical section 350 inches long. The forward nose cone has a 25° cone angle and is 182 inches long. The aft cone is 142 inches long with a 12.5° cone angle. The total length of the shroud is 674 inches long and it weighs approximately 25,000 pounds.

ATM launch loads are reacted by the PS support structure located at 90° intervals on the forward end of the cylindrical section. Provisions are made in the PS for access doors. The Saturn V damping system will be attached for use during transit from the VAB to the launch pad and for servicing while on the pad.

The PS acceptance review was conducted on August 10, 1972, and the Material Inspection and Receiving Report (Form DD250) was signed on August 31, 1972. It was received at KSC on September 22, 1972, well in advance of the KSC need date.

The jettison system for shroud separation in orbit was verified through component and full scale testing at the Plum Brook Facility, Cleveland, Ohio, vibro-acoustic testing at MSC, as well as other needed tests for qualification.

At this time one item remains to be qualified in the separation and ordnance subsystem. The diode modules are inaccessible for removal before flight. While they are now a nonfunctional flight item, assurance is required that they will not contaminate the payload.

The only open problem is the resolution of the shrinkage in the linear explosive assembly as a result of environmental conditions during storage prior to shipment to KSC. It is assumed that the new thermal conditioning process and environmental control of the shipping and storage modes should take care of the shrinkage problem.

APOLLO TELESCOPE MOUNT

The ATM houses a sophisticated solar observatory. It also provides attitude control to the cluster, and, by means of its solar arrays, provides about half the electrical power used by the cluster. The ATM consists of two concentric elements. The outer element, the rack, is an octagonal structure 11 feet from side to side and 12 feet high. The inner structure is the solar experiment canister and is about 7 feet in diameter and 10 feet long. Figure 53 shows the ATM and its component parts in relation to the total Skylab cluster.

The rack, in addition to supporting the canister, supports the four ATM solar arrays and contains the components of the attitude control system, the ATM communications system, and the thermal control system that maintains the temperature of ATM equipment within required limits. The canister is mounted in the rack on gimbals which allow it to rock 2^{o} about two mutually perpendicular axes. A roll ring allows the canister to rotate about its axis. These features make it possible to point the experiments at their targets with greater precision than can be accomplished with the cluster alone.

During launch and ascent to orbit, the ATM rack is directly supported by the PS. When the shroud is jettisoned, the support structure assumes the structural support task. The ATM support structure, which connects the rack to the forward end of the fixed airlock shroud on the AM, incorporates a deployment mechanism that rotates the ATM 90^{o} from its launch position in front of the MDA to its operating position alongside the MDA. Two work stations are provided so that an astronaut can perform the EVA task of changing the cameras and film magazines for the solar telescope.

The ATM is the major in-house development task that is performed at MSFC. MSFC has the total responsibility for the design and development including the experiments produced by a number of different PI's and their contractors. From the point of view of the total mission, the ATM experiments are supported by a ground-based ob-

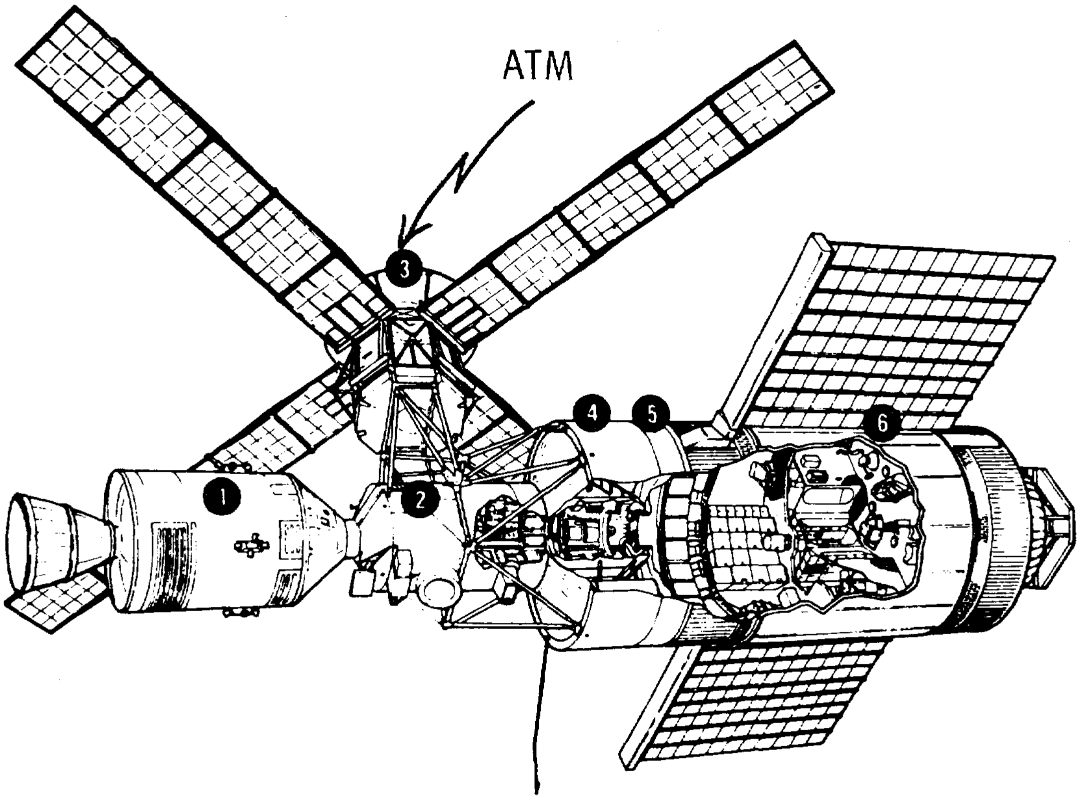


FIGURE 53

servatory astronomy program. As in any major hardware program the ATM program included a one-G trainer, thermal vibration unit, ATM prototype unit, and the necessary adjuncts.

The discussion of the ATM will include the associated experiments only as they impact the basic ATM as a module. The experiments themselves are covered in the EXPERIMENTS section of this report.

Management Aspects

A project office was set up under the Skylab Program Manager at MSFC. It used the various MSFC organizations such as engineering, astrionics, astronautics, manufacturing, and other groups. Subcontractors and vendors supplied many of the components. Because it was in-house the coordination and information flow between MSC and other affected NASA Centers was quickly and adequately set up. The geographical distribution of major elements of the ATM program are shown in figure 54. The management systems used an integrated team effort, configuration management and interface engineering, review process as well as a dedicated team of specialists to follow the ATM through testing program and the KSC test and checkout program right through launch preparations. While this was an MSFC in-house effort the same formal documentation was required as for the other modules.

The manpower varied from a high of over 2000 NASA/contractor personnel to a current number of something over 1000. The ATM program activities are shown in figure 55.

The ATM was subject to the problems inherent in a program starting in one direction in the early days of the Apollo application program and then being reoriented as the Skylab program was becoming more clearly defined. On the whole the ATM management systems and their implementation appear to be good and working well. An area that will have to be emphasized throughout the launch preparations at KSC is the cleanliness requirements in and around the ATM module.

Hardware Aspects

In its review of the ATM the Panel concentrated on the electrical power system, the attitude control system, EVA, and thermal control system. Other systems such as structures, mechanical, instrumentation, and communications were covered to a lesser extent. As in all its reviews the transferred work to KSC was a special area of interest. At the ATM preboard turnover the number of actual manhours of work to be transferred to KSC was 26 hours.

GEOGRAPHICAL DISTRIBUTION OF MAJOR ATM EFFORT

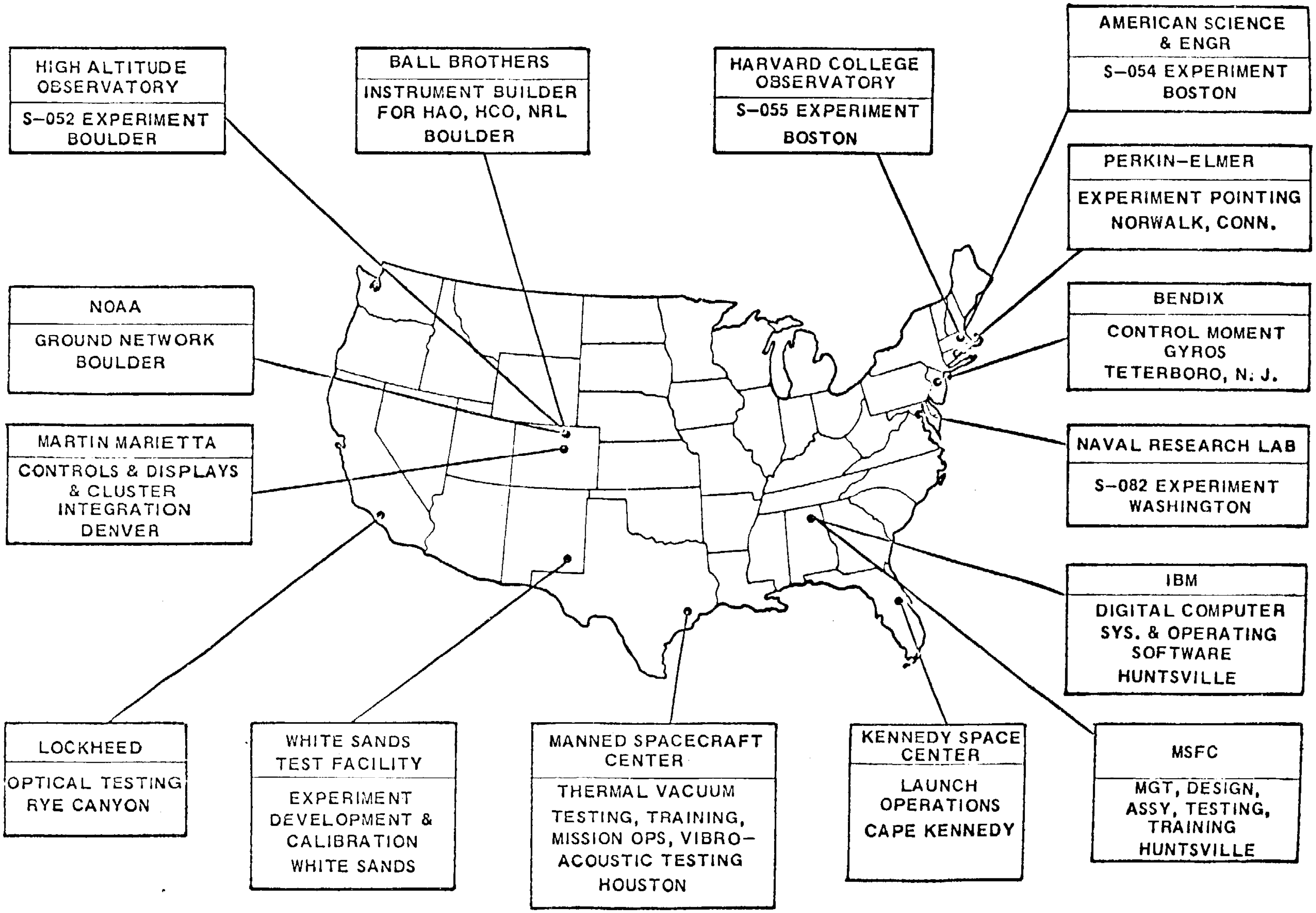


FIGURE 54

ATM CONFIGURATION DEFINITION & ASSOCIATED ACTIVITIES

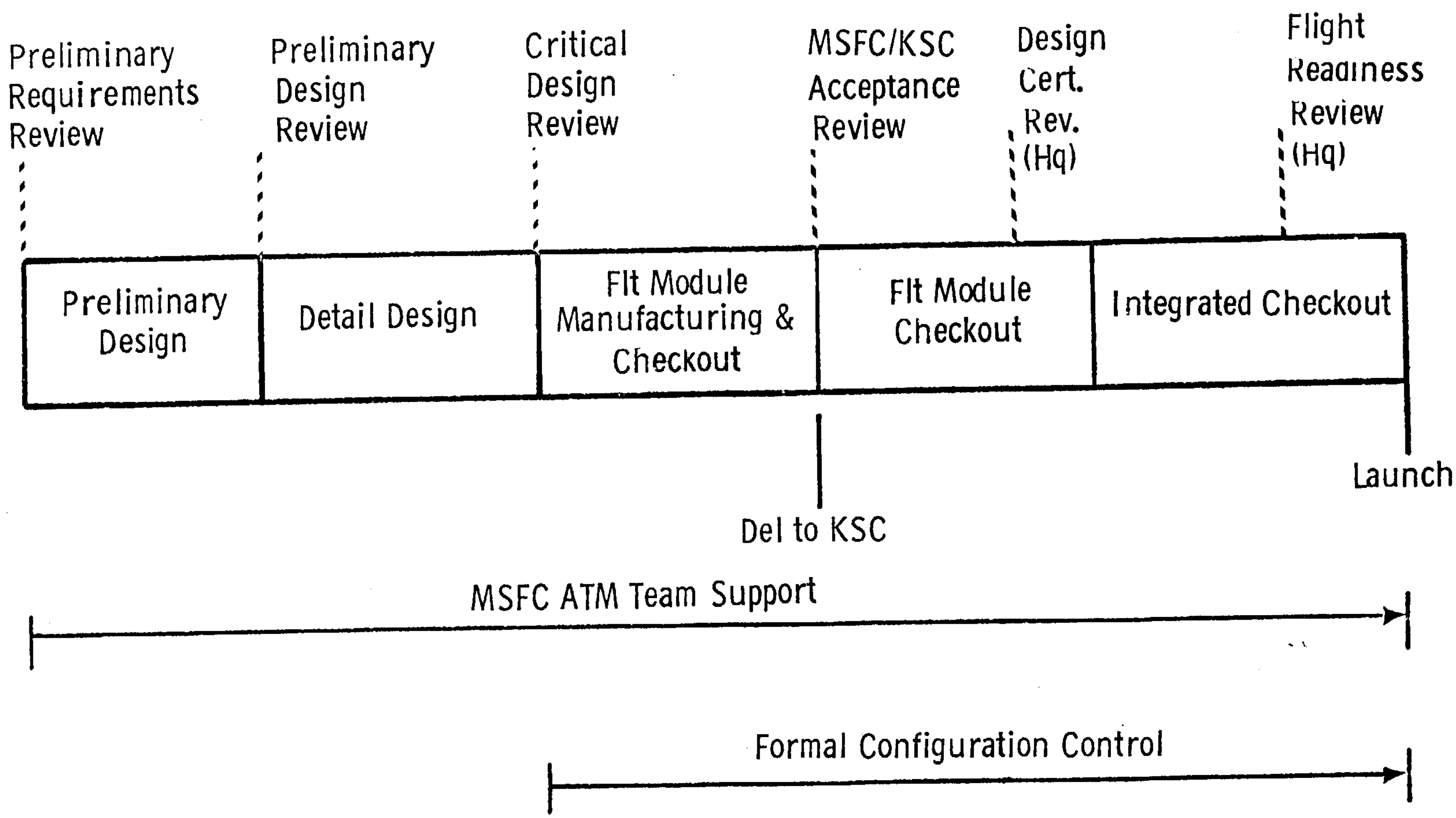


FIGURE 55

Open items at the time of the DCR included the following (closure will be noted in the next report:

1. Attitude pointing control system (APCS). Control moment gyro shutdown was due to high temperature of spin bearing during flight unit postthermal vacuum AST. Additional rate gyro processor failures were encountered during flight unit postmanufacturing checkout. Failure analysis is now in work. Test at KSC in December 1972 should close this out.

2. Electrical power system. ATM C&D logic distributor delta qualification was due to redesigned component. Expected qualification completion is in November 1972.

Other known open items are of minor impact. In examining the material issued by the Mathews team in late 1970 there were a number of items dealing with the ATM that required clarification. These included the procedures used by MSFC to check the designs, rationale for differences between the OWS and ATM solar arrays, and clarification of specific design decisions, thermal control aspects, and the reliability of the pointing system. These areas were all resolved to the satisfaction of the Mathews team.

The ATM control and display panel received a good deal of attention not only from the Panel but from the Skylab astronauts during C^2F^2 and hardware review activities. The Panel's purpose here is to use the discussion of the ATM C&D panel as indicative of the extent of coordination and effort expended by both NASA Centers (MSFC, MSC) involved in Skylab in identifying problems and resolving them. It is applicable to the entire spectrum of similar problems encountered during the development period of the Skylab and, the Panel hopes, will be the manner in which problems will continue to be resolved. An extensive set of applicable correspondence is included in section VI "Selected Background Material," on the C&D Panel. During the MSC briefing to the Panel on May 9, 1972, an assessment by the flight crew included some concerns in this subject area as noted in a memo to the Skylab Program Director:

> As a result of recent test participation, the Skylab flight crews had identified a substantial number of idiosyncrasies of the ATM C&D which required special crew procedures, or work arounds, to compensate for the actual hardware characteristics. It was pointed out that the planned ATM flight operations are already sufficiently complex that the burden of these additional workarounds would substantially reduce crew efficiency. The net effect was indicated as a very undesirable decrease in the return of ATM scientific data. Since the corrective action for these hardware idiosyncrasies was still in the consideration stage, Captain Conrad recommended strongly in favor of correcting the hardware rather than burdening the crew with the workarounds.
>
> In recognition of the adverse effect of these numerous hardware peculiarities, the ATM project personnel at MSFC have worked diligently

to correct the hardware whenever such action could be accomplished within the major program constraints. Concurrently our flight crew personnel have been directly involved in the day-by-day delibrations to achieve the most economical solutions to the hardware issues. The net result of this mutual effort is summarized in MSFC letter PM-SE/ATM-784-72 of June 12, 1972, which lists 34 ATM hardware idiosyncrasies and the corrective action planned. Of this total, MSC agreed with the resolution of 31, accepted the disposition of two without further comment, and recommended one for forwarding to the Level I CCB for resolution. . . . Subsequently, MSFC ATM engineering personnel worked out a relatively simple hardware modification with no schedule impact, and this modification has been approved for incorporation in the flight ATM C&D during the present thermal vacuum testing activities at Houston. Accordingly, this Center and the assigned Skylab flight crew personnel are now satisfied that the proper corrective hardware action has been taken to avoid any significant additional burden on the crew in operating the ATM.

EXPERIMENTS

Management of the Skylab experiments is complex because of (1) the variety of the experiments, (2) the design/fabrication requirements generated by data requirements, (3) the late definition of some experiments, (4) the requirements for integration and inte face management, (5) the number of organizations involved, and (6) the data storage and retrieval requirements. The Panel sought to understand the evolving management system in response to these factors. Particular attention was given to the maturity of the system for risk assessments. Thus, the panel reviewed experiment design and fabrication, NASA/contractor responsibilities, NASA policies affecting experiment developmen and utilization, experiment integration and compatibility with module hardware, safety assessments, current posture of the experiment program, and projected operations at KSC.

The Skylab Program Office has overall authority. Both MSFC and MSC have responsibility for the development of individual experiments. MSFC has the integration responsibility. This ultimately involves a complex of people and organizations includin experimenters, contractors for the experiments, and module contractors where interfaces are involved.

As a point of background information, the policy for scientific investigation is note here:

The following statements constitute the Skylab policy for scientific investigations which is applicable to all Skylab principal investigators. It is a general NASA policy that the principal investigator is to insure the timely processing, analyses and publication of experiment results and findings. Applicable requirements and constraints on the principal investigators for the Skylab program are as follows:

1. Principal investigators will be funded by the Skylab program for a maximum of 1 year from the time they receive the last of their flight data from the NASA Experiment Development and Operations Centers in the format as previously agreed to.

2. The principal investigators proprietary rights to the original scientific data will normally expire at the end of the 1-year period when such rights are granted in the original agreements by the experiment sponsoring program offices. NASA does not plan to grant proprietary data rights to the EREP principal investigators.

3. All original experiment data and reduced data will be available at all times for review and study by NASA by arrangement in which the principal investigators proprietary rights are fully protected.

However, NASA reserves the right to disseminate the results of any experiment or group of experiments if it can be shown that this is in the best interest of the Government. Such action would be taken only by joint direction of the Office of Manned Space Flight and the Associate Administrator of the experiment sponsoring program office.

This policy obviously effects the method of NASA/PI operations during the mission and in some cases has influence the basic working agreements with regard to the experiment hardware itself.

The management systems applied to the experiments area follow the pattern set for the modules and in the case of MSC it varies little from that used on the Apollo program scientific experiments effort. Management systems and controls consist of the following:

- Program baseline/authority
  - Program plan
  - Resources management plan
  - Configuration management plan
  - Management guides
- Status reporting and controls to assure measurement of progress against plans (performance, cost, schedule)
  - Program reviews (internal, NASA Centers, NASA/contractor)
  - Problem control and resolution
  - Intercenter and internal panels

Safety assessments

Hazard identification

Risk assessment

Verification program

Development tests

Qualification tests

Integrated tests

Reliability and quality program

The development and integration sequence used for the experiments is shown in a simplified form in figure 56. The DCR's have been completed and the experiments are essentially in checkout at KSC. Some have had to be returned to the contractor for modification. The SOCAR and the DCR efforts were obviously most valuable in determining hardware readiness and problems in both hardware and the operational documentation. An example of the areas covered during the SOCAR are shown in table XVI. The Panel has, in its reviews, received every indication that the technical management systems can resolve the existing problems. The material that follows discusses some of the hardware, problems, and status as known at this time. The purpose here is to indicate the problem solving mechanism and its ability to provide confidence in experiment risk assessment with regard to both the crew and the mission.

Crew Operations

Crew time for experiments is a prime resource in the Skylab experimental program. Use of available crew time and skill must be optimized by effective and realistic scheduling of crew activities. The problem of available crew time versus experiment requirements appears to be one that is still to be resolved during the evolution of the mission control documents. It has been noted that as a result of such tests as SMEAT the time required to accomplish certain of the experiments may be well beyond what was originally anticipated. This requires an evaluation of the policy on scheduling the crew time line. It is evident from a consideration of the variety of experiments that each crewman must be versed in several skills but that it appears best to have only one crewman selected as an expert in a given major discipline. With different experiment emphasis for each segment of the mission, the type of training and delegation of responsiblities will vary from crew to crew. Further information obtained from the Panel reviews indicates the following:

1. Because of the crews role in the biomedical program, they must have a thorough understanding of the medical experiments. A qualified observer must act as the experiment conductor when the "medical" astronaut is used as the test subject. This requires extensive cross-training in the medical area.

EXPERIMENT DEVELOPMENT & INTEGRATION SEQUENCE

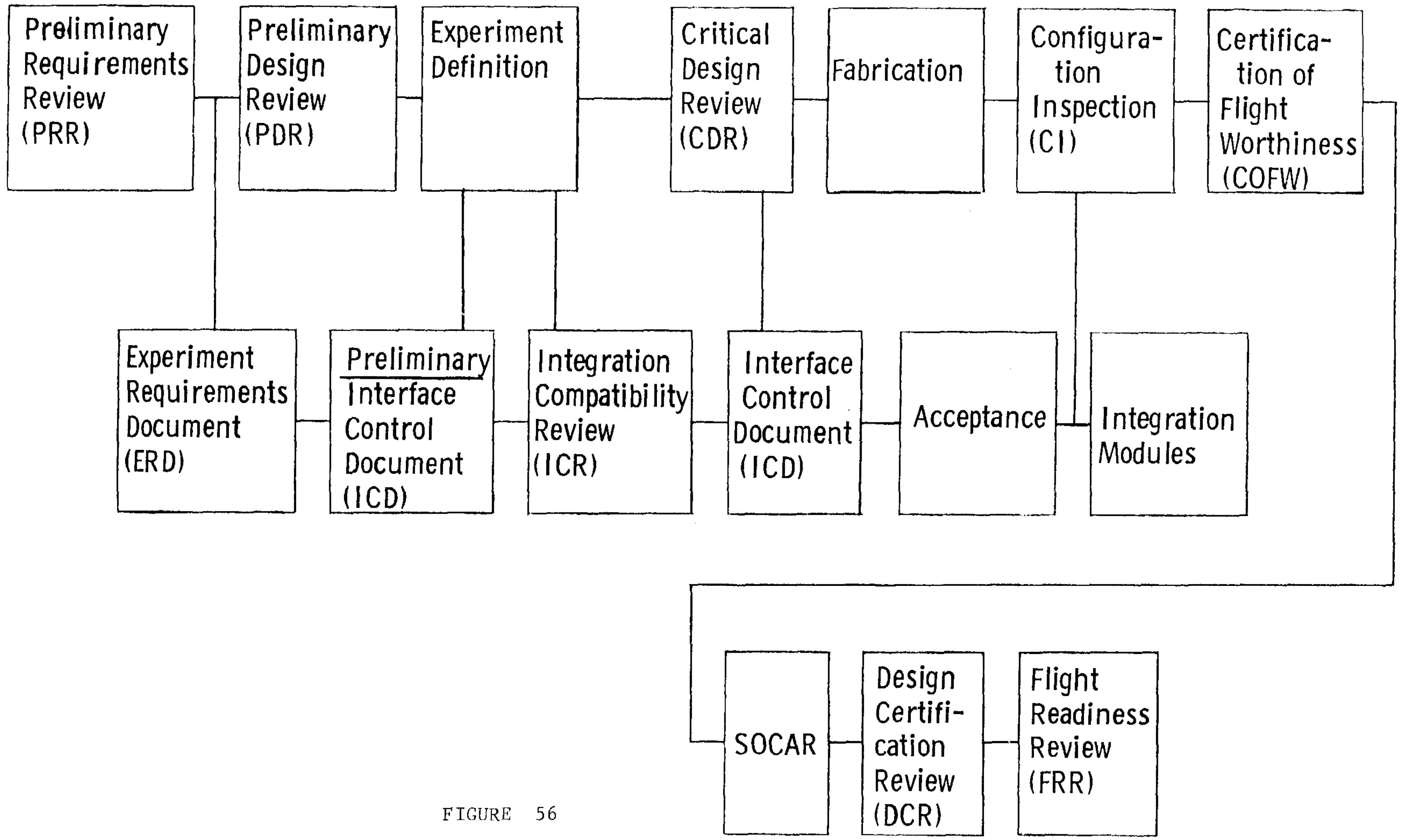


FIGURE 56

2. All three crewman must be trained to operate the ATM due to the extended periods of time planned.

3. It appears that EREP experiments require two men to operate the equipment, and attitude control operations probably require the efforts of all three crewmen.

Experiments

The experiment program consists of more than 50 items representing virtually eve field that has been recognized as being able to benefit from operations in near-Earth orbit. The instruments, sensors, and other equipment for these experiments are locat in various parts of the cluster, inside and outside. In addition to the permanently mounted items, there are two airlocks in the OWS through which scientific instruments can be operated outside the vehicle.

Medical Experiments

These experiments, including the specialized support equipment are the following (* indicates experiments integrated into the module hardware):

M071	Mineral balance
M073	Bioassay of body fluids
*M074	Specimen mass measurement
M078	Bone mineral measurement
*M092	Lower body negative pressure
*M093	Vectorcardiogram
M111	Cytogenetic studies of blood
M112	Man's immunity, in-vitro aspects
M113	Blood volume and red cell life
M114	Red blood cell metabolism
IMSS	In-flight medical support system
M115	Special hematologic effect
*M131	Human vestibular function
*M133	Sleep monitoring
M151	Time and motion study
*M171	Metabolic activity
*M172	Body mass measurement
*S015	Effects of zero-G, human cells
*S071	Circadian rhythm, pocket mice

*S072 Circadian rhythm, gnat

*ESS Experiment support system

*IBCS In-flight blood collection system

The ESS provides a central source from which medical experiments are supported with regulated electrical power, control and display panel, calibration, etc. This unit is mounted in the OWS in close proximity to the experiments it serves.

The remaining vehicle tests that impact the medical experiments are the end-to-end system tests, the experiment test at KSC, and the mission simulation/flight readiness test at KSC. The results of the SMEAT have been described, as known by the Panel at this time in the SMEAT section of this report. (M131 and M172 were not included in the SMEAT test.) Qualification tests remain to be completed on the M133 and ESS.

Experiment M071, mineral balance, is impacted by the increased requirements for urine collection noted in the SMEAT discussion. A procedure is required to use the new 4000-milliliter urine void in the mineral balance test. The complexity of the overall experiment operation and its impact on crew timeliness is a concern. The appropriate organizations at MSC and MSFC have indicated that this problem is being worked and will be covered in the operational documentation. This also applies to M073.

Experiment M092, lower body negative pressure device, has received special emphasis because of the implications for crew safety. Factors to consider include flammability, crew egress, vacuum environment, and physical crew restraint while in use. In addition, it is considered one of the most important of the medical experiments. This experiment is actually divided into three pieces of individual hardware: the lower body negative pressure device, blood pressure measuring system, and limb volume measuring system. The LBNPD prime contractor is the Marshall Space Flight Center. The prime contractor for the BPMS and LVMS is the Martin Marietta Corporation, Denver. The responsibility for the overall medical experiment M092 belongs to MSC. This experiment is indicative of those experiments involving a number of different organizations, geographically diverse, where extensive cooperation is required. Tests, FMEA, configuration control reviews, and EMI reviews have indicated problems during the development and testing of this hardware. These problems appear to have been resolved to each program element's satisfaction. The system performed well during SMEAT. Various body seals were tested. Operating limits were better defined.

The metabolic analyzer, M171, determines the metabolic rate in terms of oxygen consumption and carbon dioxide production. It is used during periods of rest and calibrated exercise. Components include an ergometer, metabolic analyzer, body temperature measuring system, and breathing apparatus. This is probably the most complex hardware of all the medical experiments. Testing of these units during AST on the OWS and the SMEAT uncovered a number of problems. These have been resolved or are in process of resolution with no other forseeable problems. It is interesting to note that the ability of the SMEAT crew to exceed expected energy inputs did cause failure of the bicycle ergometer. The operational acceptability of the oxygen consumption analysis at 5 psia appears to be somewhat of a problem. The resolution of this shall be noted in the next report.

The prime contractors for experiment M131 are the Naval Aerospace Medical Research Institute and the Applied Physics Laboratory of Johns Hopkins University. This is basically a chair device used to rotate the subject at several optional angular velocitie and it will be used to determine the effects of prolonged weightlessness on man's susceptibility to motion sickness and on his judgment of spatial coordinates. Inherent in this type of device are many potential hazards. The safety activities have identified 28 of them: mechanical, -8; electrical, -7; pneumatic, -4; and operational, -9. Each has been investigated, understood, and considered acceptable. Apparently the chair velocity was erratic after 3 months of storage and the assessment of this appeared to be open at the time of the Panel's review. The resolution of this shall be noted in the next report.

The in-flight blood collection system had not been finalized at the time of the last Panel review. Only the prototype and development units have completed testing. Flight type hardware was not expected to be available for testing until October 1972. Prototype hardware was tested in the SMEAT.

Those experiments requiring no in-flight hardware, such as M111, 112, 113, 114, 115, and others, do not have direct hardware impacts. However, they do affect the operations area. The Panel has no specific comments on these at this time. The M487, habitability/crew quarters hardware, is used for these experiments. The posture of documentation and acceptability of the small hardware elements of M487 are not known by the Panel at this time. The closure of this shall be noted in the next Panel report.

The following documentation needs to be updated. The closure of these items will be statused in the next report:

1. The Skylab biomedical failure mode and effects analysis (FMEA) documentation for the hardware components
2. The mission level FMEA documentation
3. The operational data book

Apollo Telescope Mount (ATM) Experiments

These experiments provide data on solar activities beyond that available from Earth-based observatories. Experiments included in this group are the following:

S052 White light coronagraph
S054 X-ray spectrographic telescope
S055 Ultraviolet scanning polychromator spectroheliometer

S056 Dual X-ray telescopes
S082 XUV spectrograph/spectroheliograph H-alpha telescope

The ATM as an in-house program at MSFC used the management systems described for the basic program modules. The experiment interfaces shown in figure 57 also indicate the management controls necessary to execute this program. Contamination control is vital to these experiments both on the ground and while in Earth orbit. Contamination would cause scattering and absorption in orbit and degradation of critical surfaces.

The crew interface with the ATM is extensive involving them in the operation of the experiments from inside the vehicle and the EVA required to retrieve film. The time spent by a crewman in the MDA at the ATM C&D Panel can run as high as 10 hours in a 24-hour period. The amount of time assigned to the ATM experiments in the crew timeliness can be a problem if requirements are in excess of the available time to carry them out. The problem is being assured by both the MSC/MSFC and Headquarters personnel. The following items will have to be monitored closely in the months ahead:

1. Film and camera stowage including associated C^2F^2 activities
2. Damage to AM while traversing to MDA for film loading activities
3. Resolution of problems with image clarity on the S055A

In the fabrication of these experiments a number of new and/or unique techniques were employed. These involved lubrication methods and materials, electrical discharge machining, grating fabrication, development of heat rejection windows, and film strip camera development. In all of these areas the development testing and acceptance testing indicated that the workmanship and management controls produced the desired product.

Earth Resources Experiment Package (EREP)

The EREP system includes equipment used for observing and analyzing Earth phenomena from space. These phenomena include agriculture, forestry, geology, geography, air and water pollution, and land use. The equipment includes the following:

S190A Six camera multispectral photographic facility
S190B Long focal-length Earth terrain camera adapted from Apollo
S191 Infrared spectrometer boresighted with a viewfinder and tracking system
S192 13-Channel multispectral scanner (this spectral range overlaps the S190 and S191 camera capabilities)
S193 Microwave radiometer/scatterometer and altimeter (K-band)
S194 L-Band microwave radiometer

ATM EXPERIMENT INTERFACES

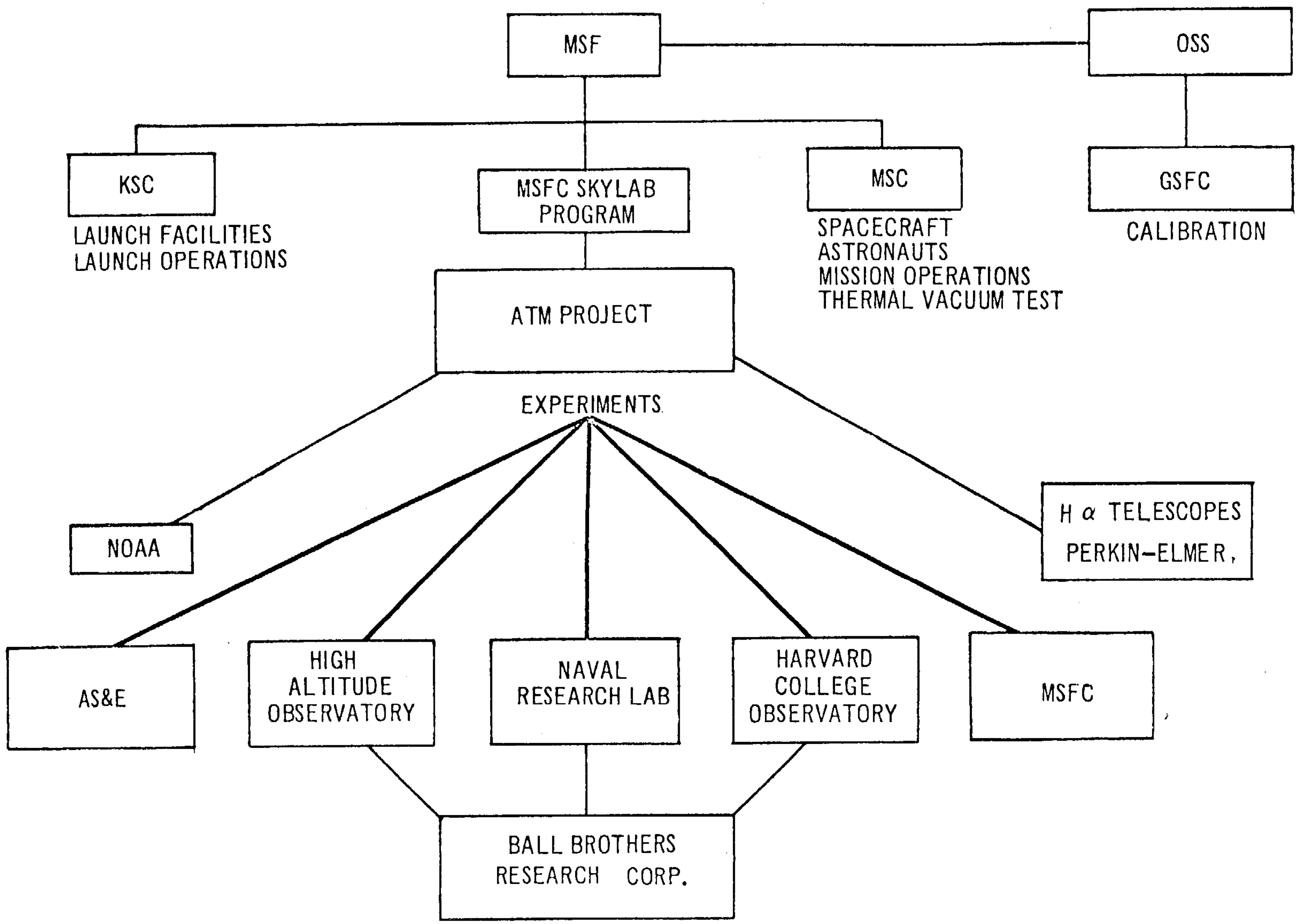


FIGURE 57

Some 106 PI's have been selected for experiments using the EREP system. These include 23 scientists from other nations. The equipment for these experiments is located in the MDA with S193 located in the AM and the S190B in the OWS. Development NEREP instruments began relatively late in the program. This resulted in the late selection of PI's and later evolution of the management systems necessary to conduct this segment of the program. These aspects of the EREP program had a salubrious effect. Greater emphasis was placed on EREP than might otherwise have been the case. On the other hand, the impact of EREP hardware problems late in the program tended to cause adverse impacts on the testing and development aspects. It also presented difficulties in maintaining a balance between operational compatibility evaluation and analysis and the activity directed toward obtaining a basic knowledge of the flight systems and the flight objectives.

The EREP support equipment include the control and display panel, tape recorder, viewfinder tracking system, S190 supplemental hardware, coolant system, structural support, etc. Indicative of the complexity and sophistication of the EREP hardware are the stowage requirements:

SL-1	Launch of the OWS, AM, MDA	188 items stowed
SL-2	Launch of the CSM	60 items stowed
	Return with CSM	157 items stowed
Each successive CSM Launch		60 items stowed

The EREP management structure to meet the requirements of this program is shown in figure 58. The major organizations involved in the hardware development are shown in figures 59 and 60. This arrangement indicates the attention given the EREP system by MSC.

Among the items still open are the following:

1. Descrepancies on S192, S193, and S194 require rework at the vendors.

2. ESE and functional interface verification for S192 and 193 will have to be completed at KSC.

3. Flight filters and desiccants for S190B have to be delivered; qualification testing has to be completed.

The closure of these items will be noted in the next report. The earlier major concern about the tape recorder and Malabee cooler appears to be resolved.

Based on the material presented to the Panel, we believe the actions being taken are appropriate. However, this is an area that will continue to require careful attention from contractors, PI's, and the NASA organizations involved. This requires continued control of ECP's, waivers, and IRN's as well.

EREP MANAGEMENT STRUCTURE

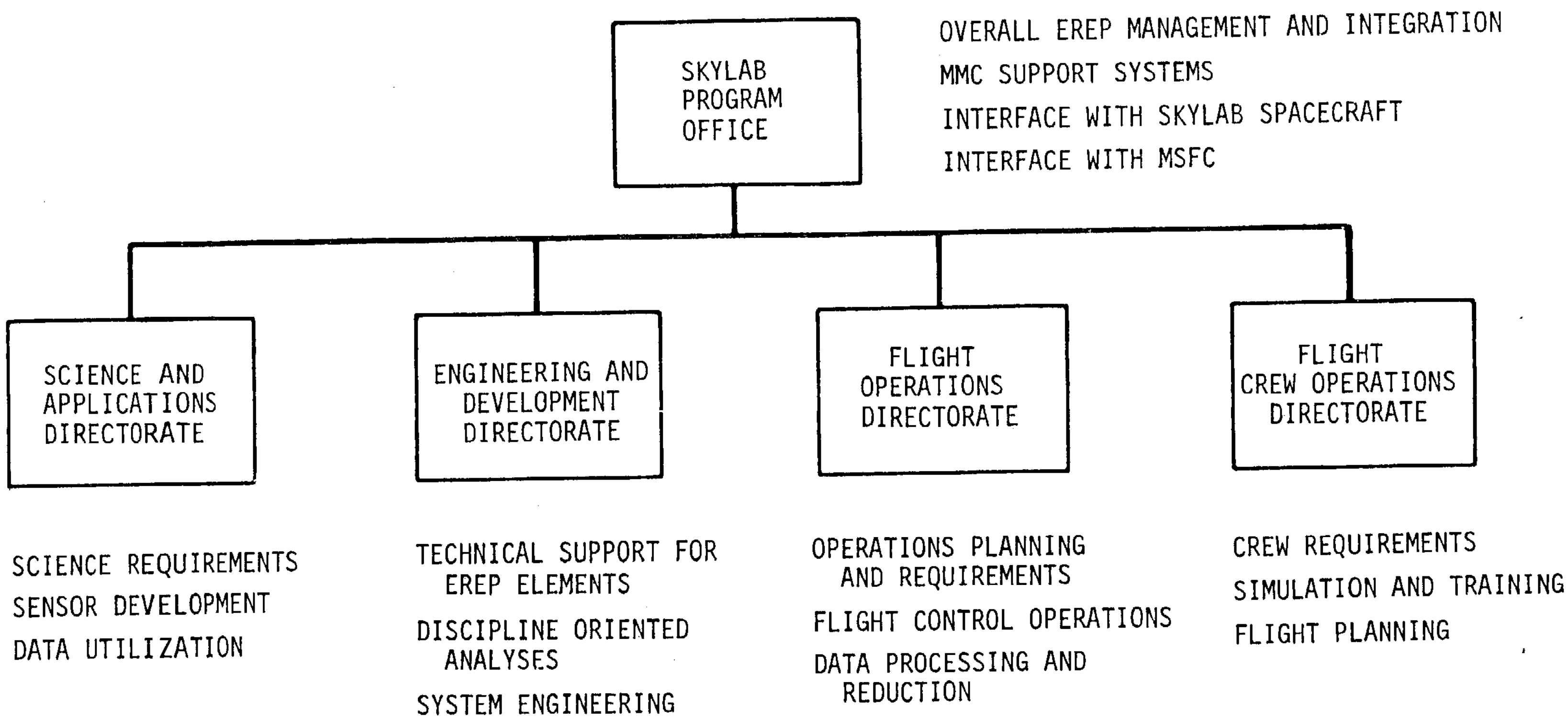
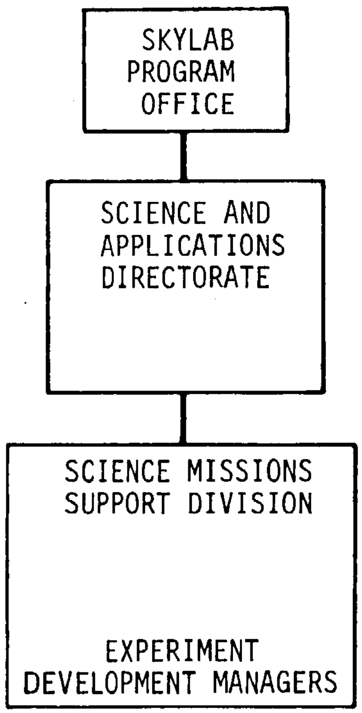


FIGURE 58

EARTH RESOURCES EXPERIMENT PACKAGE (EREP) MANAGEMENT RELATIONSHIPS



RESPONSIBLE FOR OVERALL EXPERIMENT MANAGEMENT

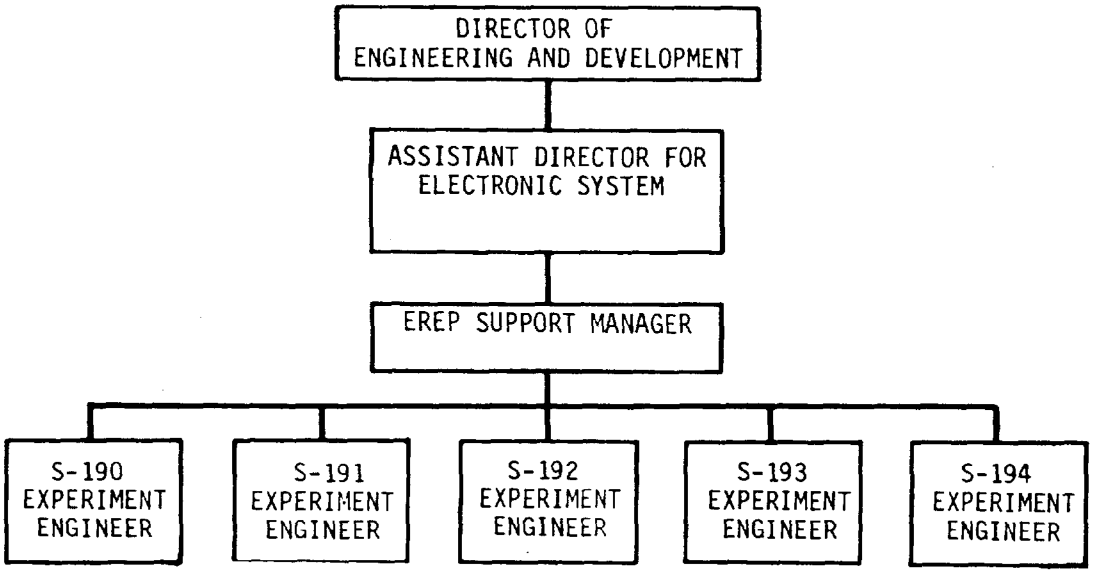
RESPONSIBLE TO SKYLAB PROGRAM OFFICE FOR SKYLAB SCIENCE EXPERIMENT MANAGEMENT

RESPONSIBLE FOR ESTABLISHING SCIENCE REQUIREMENTS AND IMPLEMENTING S&AD SUPPORT FOR SKYLAB

- EXPERIMENT HARDWARE DEVELOPMENT
- DEFINITION OF SCIENCE REQUIREMENTS
- SCIENCE EXPERIMENTS MISSION PLANNING
- ASSISTANCE IN CREW EXPERIMENT TRAINING
- REAL-TIME OPERATIONAL SUPPORT
- MSC POINT OF CONTACT FOR PI's

FIGURE 59

ENGINEERING AND DEVELOPMENT DIRECTORATE



1. ELECTRONICS CIRCUITRY AND PACKAGING
2. STRUCTURAL/THERMAL
3. GSE
4. INTEGRATION
5. TESTING
6. DATA SYSTEM
7. OPTICS
8. POWER DISTRIBUTION

FIGURE 60

Corollary Experiments

This group of experiments consists of all those experiments that do not fit into the three group-related classifications already discussed: -ATM, biomedical, EREP. All of the scientific airlock (OWS), astronomy, and photographic experiments are included in this category. These experiments are located throughout the cluster in the OWS, AM, and MDA. A thermal control coatings experiment (passive) located on the IU. Each of the modules provides the necessary accommodations for electrical, mechanical, and other support. One of these experiments is developed by the French Government, S183 Ultraviolet Panorama. Ten additional experiments in metals and materials processing were recently made possible by the development of the M518 multipurpose electric furnace system to replace the composite casting furnace. The Skylab experiments in M518 will explore and pioneer some of the potentially practical uses of manufacturing and processing techniques not possible on Earth.

All of these experiments and their supporting hardware have been subjected to the same review cycle applied to the modules and experiments. The SOCAR effort involved a specific team to cover the corollary experiments. The crews have gained a detailed understanding of experiment hardware, and they have provided much needed support in the development of those items through participation in reviews, C^2F^2 tests, training, and simulations. A large number of special studies have been conducted to assure the adequacy of design and operations. These cover

Unattended SAL experiment operations
Retraction, extension, and ejection of SAL experiments
Capability of the universal extension mechanism system
Velocity hazards from operations of T020, M509, and T013
FMEA's

The SOCAR and DCR's, including the activities leading up to them, identified problems and established means for solving them. Much has yet to be accomplished in preparing the operational documentation. This will continue to require management attention. However, the management structure gives us confidence that the hardware and operations planning will support mission requirements.

BIBLIOGRAPHY

Because of the vast number of documents associated with the Panel's reviews, only those of specific note are given here. The remainder are simply noted under the four titles of SOCAR, DCR, PDTR, and SAR.

"Third Annual Report to the Administrator," Aerospace Safety Advisory Panel, Feb. 1972.

"Skylab Design Certification Reviews," Skylab Program Directive No. 17, March 7, 1972.

"Establishment of Skylab Program Interface Panel Organization," Skylab Program Directive No. 7A, March 18, 1970.

"Reliability, Quality & Safety Auditing," Skylab Program Directive No. 9.

"Nonconformance Reporting & Corrective Action," Skylab Program Directive No. 10A.

"Sequence and Flow of Hardware Development and Key Inspection, Review and Certification Checkpoints," Skylab Program Directive No. 11A.

"Failure Mode and Effect Analysis - Single Failure Point Identification and Control," Skylab Program Directive No. 13.

"Skylab Program Materials Policy," Skylab Program Directive No. 16A.

"Implementation of System Safety Requirements," Skylab Program Directive No. 31.

"An Etiological Study of Phthalate Self-Contamination of Spacecraft and Contamination From Their Earthly Environs," NASA Technical Note D-6903, 1972.

"Human Factors in Long-Duration Spaceflight," National Academy of Sciences, 1972.

"Skylab Orbital Assembly Fire Study," MSC-04084, April 15, 1971.

"Skylab System Safety Checklists" SA-003-002-XX. This series of documents issued by MSFC to determine status of GSE, flight systems, and experiment hardware.

SOCAR Reports, May and June 1972.

DCR Documentation, May-Oct. 1972

PDTR Documents, Aug./Sept. 1972

SAR Documents, Sept. 1972.

TABLE I. - SKYLAB SYSTEM SAFETY CHECKLISTS

[Typical source data for checklist development.]

Manned Space Programs Accident/Incident Summaries	NASA, Director of Safety, March 1970
System Safety Accident/Incident Summary	NAR, Space Division, July 1967
Air Force Eastern Test Range Safety Manual, Vol. 1	AFETRM 127-1, January 1, 1969
Minutes, System Safety Network Technical Interchange Meetings	
Space Flight Hazards Catalog	MSC 00134, Revision A, January 1970
Management Manual Technical Information Bulletins	MSC-M8081, January 1970
Space Flight Hardware Accident Experience Report	MSFC, October 14, 1966
Apollo 14 Safety Assessment	MSC-SN-1-174-10, December 2, 1970
Air Force Systems Command Design Handbook, series 1-0	DH 1-6, July 20, 1968; Revised July 20, 1970
Report of Apollo 204 Review Board, all appendixes	1967
Report of Apollo 13 Review Board, all appendixes	June 15, 1970

TABLE II. - EXPERIMENT/SYSTEMS DESCRIPTION

Experiment	Description
M071 - Mineral balance	Measure the gains and losses of various metabolic constituents from the body; measure changes in circulating levels of several metabolites to assess nutritional status and muscular-skeletal function.
M073 - Bioassay of body fluids	Evaluate the endocrinological inventory before, during, and after exposure to simulated spaceflight environment, foods, fluids, and workloads for extended periods.
M074 - Specimen mass measurement	Weigh feces, vomitus, and food residue generated in the simulated space environment and evaluate the measurement device for Skylab use; supports M071 and M073 analyses.
SMEAT food system	Evaluate the SMEAT/Skylab food system in a simulated space environment. Provide crew with controlled Skylab diet for successful evaluation of medical experiments that are based on nutritional intake.
M092 - Inflight lower body negative pressure	Obtain baseline ground-based data concerning the time course of cardiovascular deconditioning during long-term confinement and predict the degree of physical impairment that is to be expected upon return to normal activity. Obtain verification of procedures and crew operational capability.
M093 - Vectorcardiogram	Determine reference data and changes in the electrical activity of the heart caused by exposure to the SMEAT atmosphere and other specific stressors. Correlate the changes that are detected with those known to occur after specific stress in normal environments.
M171 - Metabolic activity	Evaluate the metabolic rate measurements of man while resting and doing work during prolonged exposure to the SMEAT atmosphere and compare these results with those obtained in normal sea level environment.
M133 - Sleep monitoring	Evaluate sleep quality and quantity during extended simulated space environment.
Operational bioinstrumentation system	Evaluate response parameters and operational adequacy in the simulated space environment.
SMEAT shower	Evaluate shower for operational suitability and adequacy as a body bathing system.

TABLE II. - Concluded. EXPERIMENT/SYSTEMS DESCRIPTION

Experiment	Description
SMEAT sleep restraint	Evaluate the Skylab baseline sleep restraint and the alternate sleep restraint for crew comfort and operational suitability.
Skylab urine system	Evaluate and verify proposed in-flight procedures, operational suitability, and design adequacy of the Skylab urine system prototype.
Chamber environmental microbial monitoring	Provide habitability, environmental aerosol, surface bioburden information.
SMEAT environmental noise	Evaluate quantitatively and qualitatively the effects of continued exposure to noise in the simulated space environment.
Atmosphere analyses	Identify and quantify trace contaminants encountered during the chamber test.
In-chamber CO_2 measurement	Use and evaluate the Skylab CO_2/dewpoint monitor; obtain knowledge and control of in-chamber CO_2 levels.
In-chamber CO measurement	Provide capability for crew monitoring and warning of out-of-tolerance in-chamber CO levels.
T003 - Aerosol analysis	Measure and collect in-chamber aerosol particulate matter as a function of time and location.
M487 - SMEAT habitability/crew quarters	Establish protocol and optimize subjective rating scales for elements of SMEAT/Skylab habitability and evaluate equipment use.
M151 - Time and motion study	Evaluate crew activities during performance of operational and experimental tasks in the simulated space environment.
Skylab data acquisition simulation	Evaluate mission rules and operations documents/Flight Operations Division data evaluation and handling procedures in a real time Skylab mission time frame with simulated manned space flight network (MSFN) coverage.
SMEAT housekeeping	Obtain information on frequency, duration, and crew acceptability of housekeeping requirements during a simulated long-duration mission; confirm predicted timelines for Skylab housekeeping activities.
SMEAT personal hygiene	Evaluate personal hygiene activities in the simulated space environment for extrapolation to the Skylab mission, crew evaluation of hygiene hardware, and consideration areas.
M078 - Bone mineral measurement	Measure any loss of bone mineral content during the simulated space environment to provide baseline information for Skylab mission use - prechamber and postchamber requirements only.

TABLE III. - VENT CHARACTERISTICS

Vent number	Vent	Effluent	Flow rate, lb/sec	Frequency	Days per mission	Velocity, m/sec	Vent size, in. diam.	Remarks
6	Oxygen purge	Oxygen	0.01	2 min/24 hr	14 to 18	300	0.21	No particulate
7	Hydrogen purge	Hydrogen Water vapor	0.012 .012	4 min/48 hr	14 to 18	300	0.21	No particulate
9	M512	Metallic vapors, nitrogen, oxygen, exothermic reaction products	0.001 to 0.05 (over short time intervals)	5 times total	6 to 10	300	4	Acceptable
	M479	Combustion products, nitrogen, oxygen, water vapor, particles	0.0001 to 0.1 (over short time intervals)	37 times total	2 to 6	Particles - 0.3; Gasses - 300	4	Testing
10	MOL sieve	Water vapor, oxygen, nitrogen, carbon dioxide	0.01 average (continuous)	Continuous (15-min cycles)	All	300	2 vents, 3 (each)	No particulates testing
13	EVA depress vent and hatch	Oxygen, nitrogen, carbon dioxide, water vapors	0.14 average for 30 sec	SL 1/2 - 1 SL 1/3 - 2 SL 1/4 - 2	1 to 2	300	2.75	Acceptable
19	Waste tank	Water vapor, hydrogen, oxygen, urine, sweat, food components, respiration products, biocides	16.7 lb/day normal; 29.4 lb/day full contingency	Continuous	All	Vapor - 300; Particles - 1-20	$1\frac{1}{2}$	New filter testing
21	M092 LBNP	Cabin atmosphere, sweat	0.05	9 times/mission	3	300	0.4	Acceptable
	M171	Breath products	Infinitesimal	2 to 3 times/day	All	300	0.4	Acceptable
22	SAL	Cabin atmosphere	0.001 to 0.05	6 to 12 times/mission	All	300	0.125	Acceptable

TABLE IV. - MAJOR COMBUSTION PRODUCTS OF SOME SKYLAB MATERIALS

Test material	Major combustion products
Polybenzimidazole (PBI)	Carbon monoxide, carbon dioxide, nitrogen dioxide, nitric oxide, cyanogen, methane, and benzene
Nylon fabric	Nitrogen dioxide, nitric oxide, carbon monoxide, carbon dioxide, methane, and ethylene
Paper	Carbon monoxide, carbon dioxide, and methane
Rayon terry cloth	Carbon monoxide, carbon dioxide, methane, ethylene, normal butanol, acetylene, and ethane
Methyl vinyl silicone	Carbon monoxide, carbon dioxide, methane, ethylene, and normal butanol
Teflon sheet	Carbon tetrafluoride, carbonyl fluoride, carbon monoxide, and carbon dioxide (minor constituent)

TABLE V. - SKYLAB FLIGHT CREW

TRAINING PROGRAM (HR PLANNED)

Activity	SLM-1	SLM-2	SLM-3
Briefings/reviews	450	450	450
Systems training	350	250	250
EVA/IVA	156	184	161
Medical	98	98	98
Simulators	695	695	695
Experiments	430	461	381
Total	2179	2138	2035

TABLE VI. - SUMMARY OF THE TEST PROGRAM REPORTS CLOSEOUT STATUS AS OF 9/1/72

FOR ORBITAL WORKSHOP

Items	Test program reports	Items	Closed	MDAC open	NASA open	NASA/MDAC open
Combined subsystem	933	933	920	[a]10	1	2
C^2F^2 experiment bench check	1	67	36	1	30	0
C^2F^2 stowage bench check	↓	75	55	[b]15	4	1
C^2F^2	↓	203	192	[b]8	2	1
Delta C^2F^2	↓	42	21	[c]19	2	0
Delta C^2F^2 dome locker	↓	31	2	[c]26	2	1
All systems test	119	119	116	3	0	0

[a]Subsystem TPR's are closed except for a few items waiting completion of inspection records.
[b]Stowage bench check and C^2F^2 items are open for decal changes, missing hardware, etc.
[c]Delta C^2F^2 items were opened within the past few days and are still being worked.

TABLE VII. - TEST OBJECTIVES NOT YET SATISFIED

	Subsystem open items	Remaining components to be qualified
Crew equipment	1	0
Ordnance	0	↓
Caution and warning	↓	↓
Electrical power	↓	↓
Solar array system	↓	↓
Structures	3	↓
Communication and data acquisition	0	2
Thruster attitude control system	0	4
OWS experiments	0	6
Environmental/thermal control	1	7
Habitability support system	6	10

TABLE VIII. - LEAKAGE ALLOCATION SUMMARY

	lb/day of oxygen/ nitrogen at 5 psia during habitation		lb/day of oxygen/ nitrogen at 5 psia during storage
Allocations for component leakage			
Total		3.513	3.617
Dumps and purges (HSS usage):			
Waste processor (4 operations/day)	0.037		
Trash airlock (5 operations/day)	.650		
Liquid urine purge (3 operations/day)	.020		
Total		0.707	0
Contingency (including leakage from welds and other elements of basic structure)			
Total		0.780	1.383
Total (lb/day)		5.000	5.000

TABLE IX. - WASTE TANK - TRASH DISPOSAL AIRLOCK PROBLEM SUMMARY

Problem	Solution
Absolute pressure gage - failed in first phases of vibration testing	Made more rugged; retested successfully
Outboard hatch - drifted from its exact center after cycling due to brinnelling of aluminum hub for antirotational bolt	Tension strut was added; retested successfully
Pressurization valve plug - plug land galled causing valve handle load increase, bore also galled	Land was turned down to give clearance with bore; handle load reduced to acceptance level; continued testing with no further problem
Inboard hatch latch - galling between latch eccentric and mating part due to lack of proper lubricant caused excessive latch loads	Solid film replaced with krytox grease; testing continued successfully

TABLE X. - REFRIGERATION SYSTEM

System provides equipment for	Temperature, °F
Frozen food	-20 to +0
Food chilling	+33 to +45
Water chilling	+33 to +45
Urine chilling	+59 (max)
Urine freezing	-2.5 (max)

TABLE XI. - FIRE SENSOR LOCATION AND READOUT LOCATION

Sensor location	Readout location	Fire location
Wardroom sensor 2	Control panel	OWS crew quarters
Wardroom sensor 1		
Waste management compartment	Control panel	
Sleep compartment 1		
Sleep compartment 2	Control panel	
Sleep compartment 3		
Experiment compartment 3	Control panel	OWS experiment compartment
Experiment compartment 2		
Experiment compartment 1	Control panel	
Forward compartment 3	Control panel	OWS forward compartment
Forward compartment 2	Control panel	
Forward compartment 1		

TABLE XII. - OWS GENERAL ILLUMINATION SYSTEM PROVIDES GENERAL ILLUMINATION AT AVERAGE LEVELS

[System provides initial entry and emergency mode illumination of 0.5 footcandle (min) in crew quarters and forward compartment.]

Area	Footcandle (min)
NASA sleep compartment	4.5
Wardroom	5.0
Head	9.0
Experiment compartment	5.5
Forward compartment	1.0

TABLE XIII. - OWS STOWAGE LOCKERS NOT REVIEWED AT HUNTINGTON BEACH (8/31/72)

[Those stowage lockers which have been reviewed and have open TPR items against them at time of shipment are not included in this list.]

Stowage lockers	Reason for no review
D420	No flight data file maps, no ergometer restraints
D448	No triangle shoes
F507	No A9 locker contents
F517	No blood sample spacers, etc.
F519	No blood sample spacers, etc.
F567	Redesign ETC window bracket not available
F573	No ETC stowage locker
W703	No high school student experiment equipment
W704	Inadequate quantity of food supplements available
W714	Final flight entertainment equipment contents not available
W749	M487 flight hardware not available
W754	On-orbit configuration not reviewed (food cans plus IMSS)
W769	No fecal tracers
H810	No blood sample equipment
H820	Squeezer bag stowage so unacceptable needs complete rereview
H823	Urine bag dispenser locker not available
S901	No sleep restraints
S902	No sleep restraints
E610	Final flight biomedical equipment contents not available
E615	Final flight biomedical equipment contents not available
S903	No sleep restraints
S909	No triangle shoes
S921	No triangle shoes
S931	No triangle shoes

TABLE XIV. - STRUCTURES AND MECHANICAL SUBSYSTEM

SYSTEM PERFORMANCE SUMMARY

Component/subsystem	Factor of safety, actual minimum effective[a]
Airlock module:	
AM basic structure (STS, tunnel, trusses)	1.25
EVA hatch: compartment (including internal hatches)	2.15
Nitrogen bottles mounting	2.00
AM/OWS bellows	2.00
STS windows	3.79
Mechanisms (latches, etc.)	2.00
AM/MDA radiators	[b]13.00
Transportation and handling equipment (as affects flight hardware)	[b]4.00
Apollo telescope mount deployment assembly:	
ATM/DA basic structure	[b]5.0
Deployment mechanisms	[b]3.0
Rigidizing mechanisms	[b]5.0
FAS attachments	[b]8.0
Transportation and handling equipment (as affects flight hardware)	[b]4.0

[a]Effective factor of safety defined here as factor of safety that will result in a zero margin of safety: Effective factor of safety = Capability/Applied load.

[b]No structural verification tests.

TABLE XV. - INSTRUMENTATION AND COMMUNICATION SYSTEM PERFORMANCE SUMMARY FOR AM DATA SUBSYSTEM

Basic requirements	Capability	Verification
Monitor and process signals from experiments and module subsystems	575 Transducers and 250 signal conditioners provide outputs to approximately 1250 telemetry channels, 80 displays, and 25 C&W channels	All subsystem requirements have been verified by analysis and test program which includes development, qualification, acceptance, and special functional compatibility and interface testing
Multiplex and encode data from experiments and module for transmission to STDN	Programmer, interface box, and 25 multiplexers provide 1298 analog and discrete channels, 1035 of which are recordable	SWS/STDN compatibility testing was performed at GSFC All testing has been completed except:
Record voice and data	Each of three tape recorders provide 180 minutes record capability with playback in 8 minutes per recorder	Mission support engineering, will be completed by April 1, 1973 Intrasubsystem waveform, will be completed by January 15, 1973
VHF transmission link to STDN via antennas which provide coverage during all mission phases	One launch and three on-orbit transmitters modulated by six different sources provide launch and on-orbit coverage via discone and UHF stub antennas; hardline cable provides prelaunch data coverage	Tape temperature, will be completed by March 1, 1973 Qualification of -- PPO_2 sensor, will be completed by November 7, 1972 TACS temperature sensor, will be completed by October 31, 1972 TACS pressure sensor, will be completed by October 20, 1972 OWS gas flowmeter, will be completed by April 13, 1973 Delta qualification of tape recorders, will be completed by December 31, 1972 Systems acceptance of tape recorders, will be completed at KSC by February 5, 1973

TABLE XVI. - SKYLAB SYSTEMS/OPERATIONS COMPATIBILITY ASSESSMENT REVIEW (SOCAR) PLAN REVIEW TOPICS

Systems design
Systems performance predictions
Systems operation constraints and limitations
Systems interfaces - functional
Waivers and deviations
Test and test anomalies
FMEA/SFP
Safety checklists
In-flight maintenance tasks
Contingency analyses